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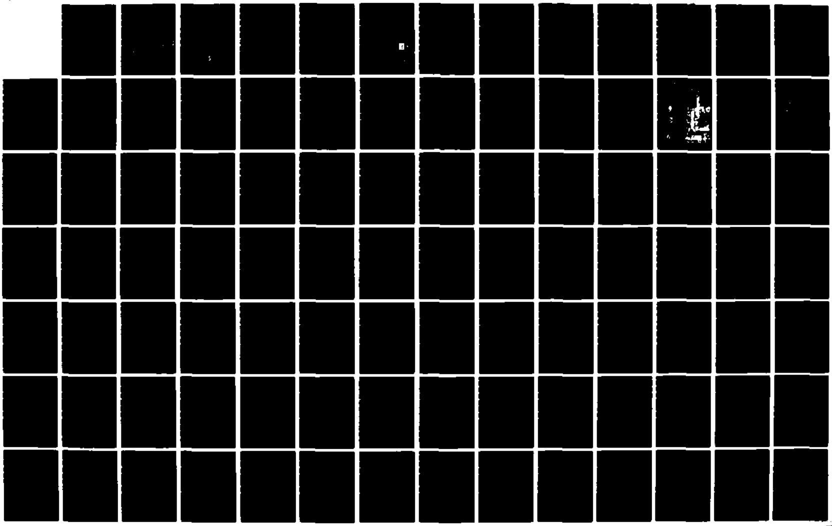

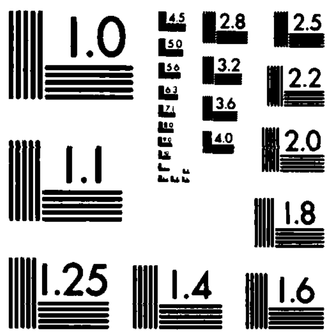

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AD-A153 207

A Technical Report

Grant No. N00014-85-G-0086

Third TIMS/ORSA Special Interest Conference on Applied Probability COMPUTATIONAL AND STATISTICAL PROBLEMS IN PROBABILITY MODELING

Submitted to:

Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217

Attention: Program Manager, Statistics and Probability

Submitted by:

C. M. Harris
Professor

Project NR042-534

Report No. UVA/525393/SE85/108
January 1985

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

DEPARTMENT OF SYSTEMS ENGINEERING

UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VIRGINIA 22901

(1)

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Department of Systems Engineering
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UNIVERSITY OF VIRGINIA
CHARLOTTESVILLE, VIRGINIA

Report No. UVA/525393/SE85/108
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January 1985

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Conference, Probability, Computational Problems. Statistics, Applied Probability,

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The third special interest meeting of the ORSA/TIMS Applied Probability Group was held at the Fort Magruder Inn in Williamsburg, Virginia, from January 7-9, 1985. There were 143 participants in attendance, including seven students and numerous visitors from overseas.

(continued)

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Item 20. (Continued)

The objective of the conference was to stress the practical importance of both statistical and numerical issues in building stochastic models. The meeting was built around six keynote addresses which highlighted the special theme areas of the conference. The six themes were: (1) Numerical Problems in Probability; (2) Inference for Stochastic Models; (3) Simulation and Computers; (4) Time Series Modeling; (5) Real World Issues in Probability Modeling; and (6) Reliability and Survival Modeling. These distinguished plenary speakers and their titles (in order) were: [illegible] include: [illegible]

(1) Marcel F. Neuts, "Profile Curves of Queues"
(2) I. V. Basawa, "Statistical Forecasting for Stochastic Processes"
(3) George S. Fishman, "A Monte Carlo Sampling Plan for Estimating Network Reliability"
(4) Emanuel Parzen, "Time Series Model Identification and Quantile Spectral Analysis"
(5) Julian Keilson, "Real World Issues in Probability Modeling"
(6) Richard L. Smith, "Statistics of the Three-Parameter Weibull Distribution"

In addition to these, there was an evening plenary session in which Nozer D. Singpurwalla talked about "The Relevance of the Bayes Paradigm in Applied Probability." Professor Singpurwalla's presentation was accompanied by very spirited response from two discussants, Lyle Broemeling and Edward Wegman.

The meeting included parallel sessions in the late morning and throughout the afternoon. There were a total of 84 talks, including three presented over noontime on Monday and Wednesday, while attendees munched on pre-prepared box lunches. Approximately 20 of the presentations were made on a contributed basis. Work has now begun on the Proceedings, which will be published in a refereed volume of the Annals of Operations Research in 1986.

The Third ORSA/TIMS
Special Interest Conference
on Applied Probability

COMPUTATIONAL AND STATISTICAL PROBLEMS IN PROBABILITY MODELING

PROGRAM

January 7-9, 1985

Fort Magruder Inn
Williamsburg, VA

SCHOOL OF ENGINEERING AND APPLIED SCIENCE

UNIVERSITY OF VIRGINIA

OFFICE OF THE DEAN
THORNTON HALL

CORRESPONDENT'S PHONE
(804) 924-

April 18, 1985

Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217

Attention: Program Manager
Statistics and Probability

Gentlemen:

Enclosed for your review and evaluation are twenty (20) copies of my technical report entitled "Third TIMS/ORSA Special Interest Conference on Applied Probability: Computational and Statistical Problems in Probability Modeling."

If I can be of further assistance, please contact me at (804) 924-3803.

Sincerely,

Carl Harris

Carl M. Harris
Principal Investigator

CH:lsl

Enclosures: (20) SEAS Report No. UVA/525393/SE85/108

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Ms. E. H. Pancake
Ms. R. A. Nixon
Ms. S. B. Sullivan

ARE WE BECOMING
SERVANTS OF OUR COMPUTERS?

"As I see it, it's a toss-up between a Belgian data processing machine and an American electronic computer."

(from The American Scientist)

Third TIMS/ORSA Special Interest

on Applied Probability

COMPUTATIONAL AND STATISTICAL

PROBLEMS IN PROBABILITY MODELING

January 7-9, 1985

Welcome to Williamsburg and our Conference, which is sponsored by the Applied Probability Group of The Institute of Management Sciences and the Operations Research Society of America. The conference staff, representatives of ORSA and TIMS, and the personnel of the Fort Magruder Inn would be pleased to assist you in any necessary way. They should be able to answer questions about the meeting, the activities of TIMS and ORSA, and transportation and sightseeing in and around Williamsburg.

The Fort Magruder Inn is located approximately .5 miles from the edge of Williamsburg's historic area. There is a shuttle bus making three roundtrips daily from the Inn, with times posted in the lobby. A five-minute drive in the opposite direction takes one to Busch Gardens and the Old Country. Jamestown is just ten minutes further, while Yorktown is yet another ten minutes away.

All attendees are cordially invited to be guests at a welcoming reception on Monday evening, 6-8 p.m., at Alumni House on the campus of the College of William and Mary, cohosted by the Applied Probability Group, the Department of Mathematics of the College, and the Department of Systems Engineering of the University of Virginia. Carpools will be formed following

Monday's final session to transport participants to the reception.

Communications

The telephone number for contact with the conference is (804)220-2250. There will be a message board maintained outside the meeting rooms. Persons attending the meeting are encouraged to check for messages periodically throughout the meeting.

Guidelines for Attendees, Speakers and Session Chairs

General:

1. All session chairs, speakers, and meeting attendees, whether or not TIMS/ORSA members, are required to register for the meeting and pay the appropriate fees.

2. The Societies have established a policy of NO SMOKING in any technical session.

3. Requests for papers presented at the meeting should be made directly to the speaker, not to the session chair or members of the meeting committee.

4. There will be refreshment breaks outside the meeting rooms at 10:30 each morning and at 4:00 each afternoon. Coffee tea, and danish will be served in the morning, while the afternoon break will feature coffee, tea, and soft drinks.

Speakers:

1. The speakers should present their papers in the order and time listed in the program.

2. Each speaker is urged to leave some time for a few questions from the floor. Please restrict your presentation to the key issues and a summary of your findings.

3. Speakers are encouraged to bring copies of their papers to their session, if possible, for distribution to interested members of the audience.

4. Participants are reminded that the meeting rooms will contain only overhead projectors and writing easels. Speakers are responsible for preparing their own transparencies.

Session Chairs:

1. All session chairs should announce and strictly enforce the time constraints on each speaker.

2. Each room will be equipped with an overhead projector and writing easel. Session chairs or speakers will be responsible for the arrangement of any additional equipment.

Business Meeting

A breakfast meeting of the officers and council of the Applied Probability Group is scheduled for 7:30 a.m. on Tuesday in the main dining room of the Fort Magruder Inn. Any attendee wishing to bring a matter to the attention of the group is welcome to join.

Thank You

The Applied Probability Group is pleased to acknowledge financial support from the Mathematical Sciences Division of the Office of Naval Research for the travel of our invited speakers from overseas.

Please note that the list of speakers on the pages following the program outline is organized by special theme area, and not by day.

The first letter of each session code is a letter to represent the day it is to be held, M = Monday, January 7, T = Tuesday, January 8, and W = Wednesday, January 9. The second position indicates the theme number, 1-6 for keynote type, 7-9 for special topic or contributed sessions, and E or L for evening or luncheon format. The final alphanumeric is either a T for theme keynote talk or a sequence number.

All sessions will be held in the East Wing of the Conference Center. The keynote talks will be held in a combined General Hill's and General McClellan's Rooms. Brief introductory remarks will open each day's proceedings at approximately 8:30 a.m. For the pairs of late morning and afternoon sessions, General Hill's and General McClellan's Rooms will be separated. The late afternoon's three parallel sessions will be held in these two rooms in addition to General Emory's Room.

PROGRAM

	Monday	Tuesday	Wednesday
8:45-9:30 KEYNOTE ADDRESSES	Theme #1: Numerical Probs in Probability Marcel Neuts	Theme #3: Simulation & Computers G. Fishman	Theme #5: Real World Iss. in Prob Model. Julian Keilson
9:45-10:30 KEYNOTE ADDRESSES	Theme #2: Inference for Stoch Models I.V. Basawa	Theme #4: Time Series Modeling E. Parzen	Theme #6: Reliability and Survival Model. Richard Smith
10:45-12:15 each period two simultaneous sessions on day's themes (30 minutes each speaker)	Session M11-- Numerics 1 Session M21-- Statistics in Queueing	Session T31-- Simulation Session T41-- New Approaches to Time Series	Session W51-- Manufacturing Session W61-- Reliability and Survival
LUNCH	Technical Box Luncheon	OPEN	Technical Box Luncheon
1:30-4:00 each period has simultaneous sessions on main themes (30 minutes each speaker)	Session M12-- Approx and Limit Theorems Session M22-- Inference for Stoch Processes	Session T32-- Computers, Computations & Approx Session T42-- Problems in Modeling T/S	Session W52-- Case Studies Session W13-- Numerics 2
4:15-5:30 each period three/four special theme or contributed paper sessions	Session M71-- Finite Capacity Q Networks Session M72-- Nat/Phys Sci Applications 1 Session M73-- Phase-Type Applications	Session T33-- C,C, & A, 2 Session T81-- Stochastic Optim. & Control Session T82-- Queueing	Session W34-- C,C, & A, 3 Session W91-- Nat/Phy Sci Applications 2 Session W92-- Probability & Statistics
PRE-DINNER	Welcoming Reception at the College of W&M		
POST-DINNER 7:30-8:30		Special Lecture on The Relevance of the Bayes Paradigm in A/P	

SPEAKERS

M1T: 8:45 — **Numerical Problems in Probability**
Prof. Marcel Neuts - - introduced by Ralph Disney

M11: 10:45 — **Numerics 1**
Chaired by Prof. Donald Gross
Speakers: Prof. Shaler Stidham, Jr.
Dr. James McKenna
Prof. Matthew J. Sobel & Kun-Jen Chung

M12: 1:30 — **Approximations and Limit Theorems**
Chaired by Prof. Richard F. Serfozo
Speakers: Dr. Ward Whitt
Prof. Richard F. Serfozo
Profs. Donald Iglehart & Peter Glynn
Dr. Daniel P. Heyman

W13: 1:30 — **Numerics 2**
Chaired by Prof. J.G. Shanthikumar
Speakers: Profs. Robert B. Cooper & Martin K. Solomon
Dr. Bharat Doshi
Prof. Robert Foley
Dr. Martin Krakowski
Prof. William G. Marchal

M2T: 9:45 — **Inference for Stochastic Models**
Prof. I.V. Basawa - - introduced by U.N. Bhat

M21: 10:45 — **Statistics in Queueing**
Chaired by Prof. Ralph Disney
Speakers: Prof. U.N. Bhat
Prof. Winfried Grassmann
Dr. Kathleen Meier

M22: 1:30 — **Inference for Stochastic Processes**
Chaired by Prof. I.V. Basawa
Speakers: Prof. Alan Karr
Profs. W.D. Kelton & Christina Kelton
Prof. Mary E. Thompson
Prof. Yash Mittal
Profs. D. Gaver, P. Jacobs & J. Lehoczky

T3T: 8:45 — **Simulation and Computers**
Prof. George S. Fishman - - introduced by Donald Gross

T31: 10:45 — **Simulation**
Chaired by Prof. Robert Foley
Speakers: Prof. J.G. Shanthikumar
Prof. Bruce Schmeiser & James J. Swain
Profs. Matthew Rosenshine, T.I. Miles & C.D. Pegden

T32: 1:30 **Computers, Computations, and Approximations 1**
Chaired by Prof. Robert B. Cooper
Speakers: Drs. P.D. Welch, R. Nelson & P. Heidelberger
Prof. William J. Stewart & Wei-Lu Cao
Drs. Martin Reiman & Burton Simon
Drs. Stephen Lavenberg, W. Carter, A. Goyal & K. Trivedi

T33: 4:15 **Computers, Computations, and Approximations 2**
Chaired by Prof. Harry Perros
Speakers: Profs. M.L. Chaudhry, J.L. Jain & J.G.C. Templeton
Prof. Ushio Sumita & M. Kijima
Profs. Henk Tijms & A.G. de Kok

W34: 4:15 **Computers, Computations, and Approximations 3**
Chaired by Dr. Bharat Doshi
Speakers: Profs. Deniz Sandhu & Morton Posner
Prof. K.P. White
Dr. Arnold Greenland
Dr. Robert A. Crovelli

T4T: 9:45 **Time Series Modeling**
Prof. Emanuel Parzen - - introduced by Julian Keilson

T41: 10:45 **New Approaches to Time Series**
Chaired by Prof. Kent D. Wall
Speakers: Prof. Peter A.W. Lewis
Prof. Henry Gray
Prof. Stuart J. Deutsch

T42: 1:30 **Problems in Modeling Time Series**
Chaired by Dr. Wray Smith
Speakers: Dr. Wray Smith
Prof. Kent D. Wall
Profs. Samuel Woolford & Joseph Petrucelli
Profs. Joseph Petrucelli, S. Woolford, K.S. Chan & H. Tong

W5T: 8:45 **Real World Issues in Probability Modeling**
Prof. Julian Keilson -- introduced by Teunis Ott

W51: 10:45 **Probability Modeling in Manufacturing**
Chaired by Prof. Susan Albin
Speakers: Prof. E.A. Elsayed & J.J. Norton
Profs. Y.C. Ho & P.Q. Yang
Profs. David Sonderman & Frank Kaminsky
Prof. Kathryn Stecke

W52: 1:30 **Case Studies**
Chaired by Professor Linda Green
Speakers: Drs. Martin J. Fischer & Dave Calabrese
Profs. Linda Green & Peter Kolesar
Prof. Peter Purdue & Dr. Peter Malpass

W6T: 9:45 **Reliability & Survival Modeling**
Prof. Richard Smith - - introduced by Nozer D. Singpurwalla

W61: 10:45 **Reliability and Survival**
Chaired by Dr. David Harrington
Speakers: Prof. Amrit L. Goel
Dr. David Harrington
Dr. John F. Kitchin

M71: 4:15 **Finite Capacity Queueing Networks**
Chaired by Prof. Tayfur Altiok
Speakers: Profs. Harry Perros & Tayfur Altiok
Prof. Stanley Gershwin
Prof. David Yao
Prof. Rajan Suri & Gregory Diehl

M72: 4:15 **Natural and Physical Science Applications 1**
Chaired by Prof. J. Gani
Speakers: Prof. J. Gani
Mssrs. S.R.K. Prasad, C.M.K. Selvaraj & C.A. Basha

M73: 4:15 **Phase-Type Applications**
Chaired by Dr. David Heimann
Speakers: Dr. David Lucantoni
Dr. V. Ramaswami
Dr. Teunis J. Ott

T81: 4:15 **Stochastic Optimization and Control**
Chaired by Prof. Shaler Stidham, Jr.
Speakers: Prof. V.G. Kulkarni
Prof. Peter W. Glynn
Prof. Kyung V. Jo
Profs. Hsien-Te Cheng & Shelby Brumelle

T82: 4:15 **Queueing**
Chaired by Prof. J. Chandramohan
Speakers: Mssrs. B.F. Lamond & N. Van Dijk
Dr. M.F. Baccelli
Prof. David Yao & S.C. Kim
Prof. M.R. Taaffe & Kim Ong
Drs. S. Pincus & M. Saks

W91: <u>Natural and Physical Science Applications 2</u>
4:15 Chaired by Prof. Michael Taaffe
Speakers: Drs. D. Covell & F. Marchetti
Drs. D. Heimann & T. Glickman
Dr. David L. Jagerman

W92: <u>Probability and Statistics</u>
4:15 Chaired by Prof. Percy Brill
Speakers: Prof. M. Ahsanullah
Prof. H.J. Gassmann
Prof. Paul Gilbert
Prof. J.H. McCray
Prof. V. Kachitvichyanukul
Prof. Larry Leemis

TE1: <u>Relevance of the Bayes Paradigm in Applied Probability</u>
7:30 Prof. Nozer D. Singpurwalla
p.m. with discussion by Dr. Marvin Zelen
Prof. Lyle Broemeling
Dr. Edward Wegman

ML1: Technical Box Luncheon 1 - Prof. Alan Karr, Chair
12:15 Speakers: Prof. F.G. Foster
Prof. M.F. Ramalhoto

WL1: Technical Box Luncheon 2 - Prof. Matthew Sobel, Chair
12:15 Speakers: Dr. N.K. Jaiswal
Dr. Shlomo Halfin

WELCOMING RECEPTION at the College of William and Mary, Alumni House, 6 p.m., Monday, January 7, 1985.

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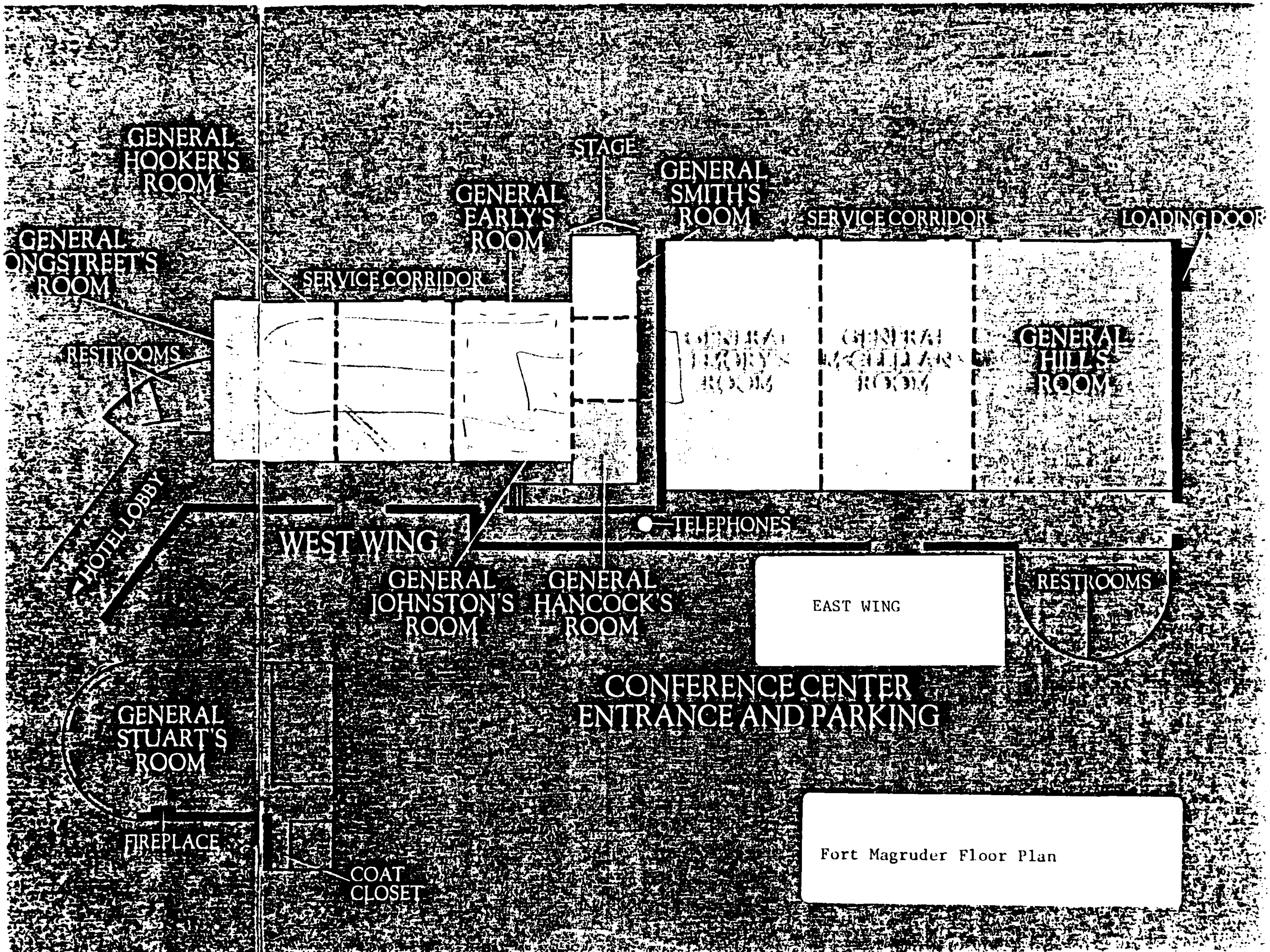
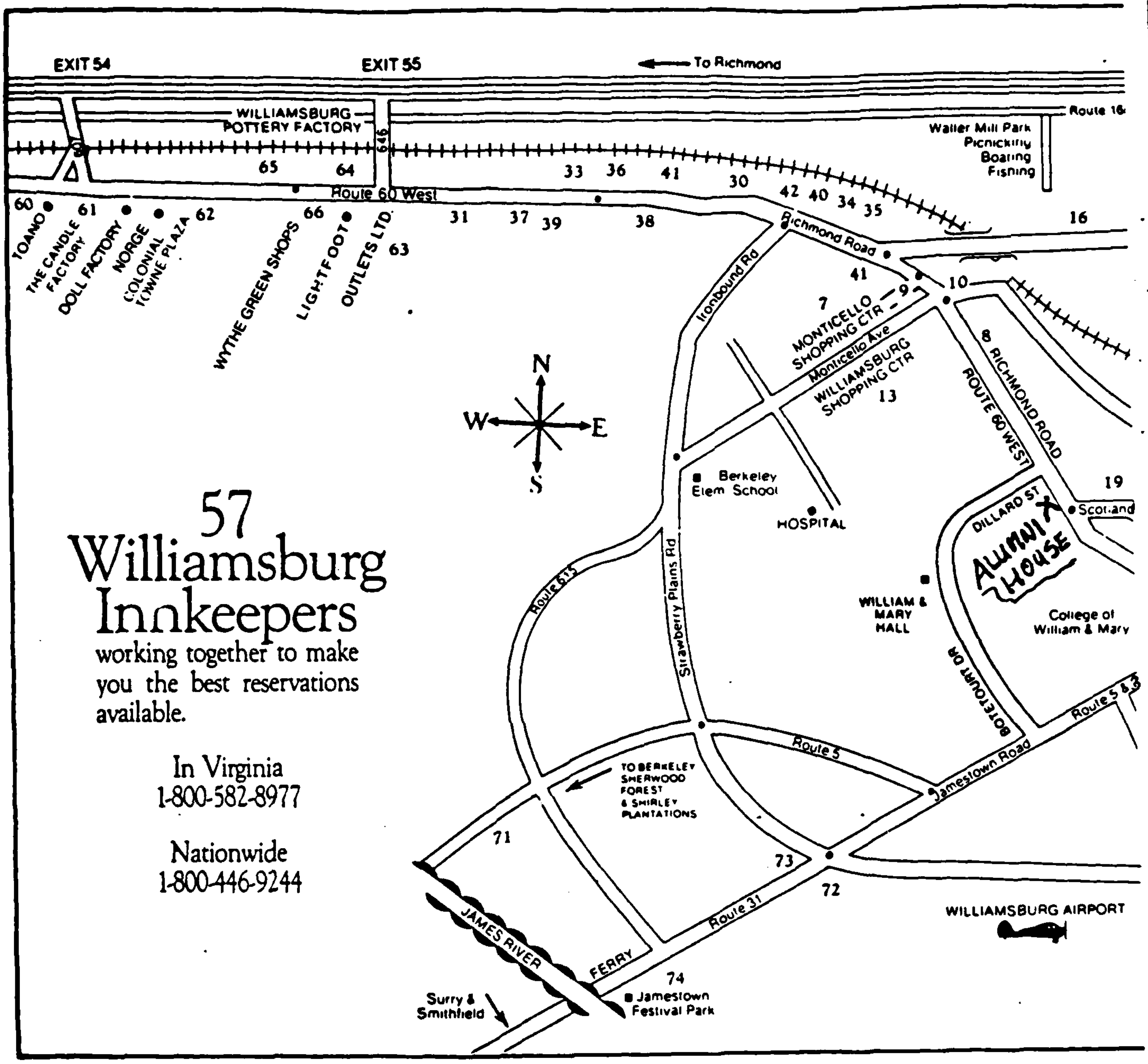


Fort Magruder Floor Plan



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Around Town
1 — Beethoven's Inn-Delicatessen
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4 — George Washington Inn
5 — Fort Magruder Inn
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9 — Heritage Inn
7 — Hsing Ling Chinese Restaurant
8 — The Lafayette Restaurant
9 — Marino's Italian Cuisine
20 — Mama Mia Pizza Restaurant
19 — Paul's Deli-Restaurant
12 — Ramada Inn East and Adam's
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14 — Second St. Restaurant & Tavern
17 — Ted's Pancakes and Italian Foods
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- Kingsmill on the James
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- Mr. Liu's Chinese Restaurant
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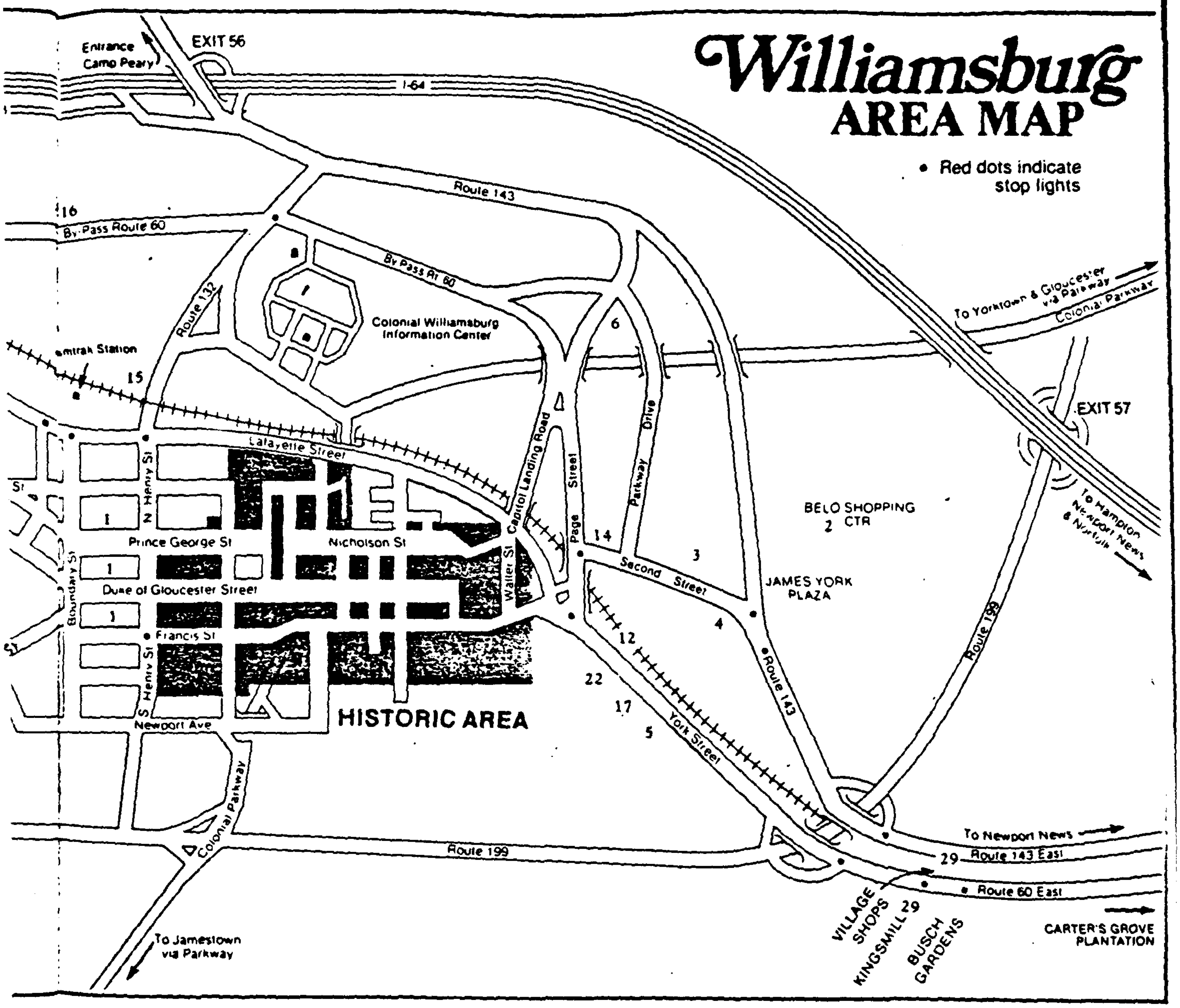

Colonial Williamsburg

a — The Cascades
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c — Chowning's Tavern
d — Golden Horseshoe Golf & Clubhouse Grill
A Good Place to Eat (in Merchant's Square)
e — King's Arms Tavern
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h — Williamsburg Inn Regency Dining Room

Richmond Road: Route 60 West

30 — Aberdeen Barn
31 — Carolina Furniture
32 — The Jefferson Inn
33 — Fireside Steak House & Seafood
34 — Giovanni's Restaurant
35 — The Lobster House
42 — Mama Steve Pancake House
36 — Mini Golf America
37 — Peddler Steak House and Lounge
38 — The Seafare Restaurant
40 — Prime Rib House
41 — Southern Pancake House

Williamsburg West

60 — Basketville
61 — The Candle Factory
62 — Colonial Towne Plaza
Fabrics Unique
Imp Pedlar
Way Station
Wiliamsburg Brass Shop
63 — Outlets Ltd.
64 — Pandy's Peanuts
65 — Wiliamsburg Pottery Factory
Pottery Factory Outlets
Manhatten Mall
66 — Wythe Green Shoppes
Light Foot Manor
Wythe Candies
67 — Williamsburg Doll Factory

Jamestown Road: Route 31 & 5

71 — Berkeley Plantation
72 — The Dower Chest
73 — Old Chickahominy House
74 — Mermaid Tavern

AUTHORS' ABSTRACTS

THIRD TIMS/ORSA SPECIAL INTEREST CONFERENCE ON APPLIED PROBABILITY

STATISTICAL AND COMPUTATIONAL PROBLEMS IN PROBABILITY MODELING

Fort Magruder Inn
Williamsburg, Virginia

January 7-9, 1985

Carl M. Harris
University of Virginia
Meeting Chairman

Robert B. Cooper
Florida Atlantic University
Chairman, Applied Probability Group
of TIMS/ORSA

Please note that:

The abstracts are arranged in alphabetical order by first author's last name, though this form of reference may not agree with the manner in which each talk is represented in the program brochure.

The listing of speakers following the abstracts provides mailing addresses, as well as indicating appropriate session numbers and the names of coauthors.

Title: Characterizations of Distributions by Using Estimates of Reliability.

Author: Mohammad Ahsanullah, Department of Decision Sciences and Computers, Rider College, Lawrenceville, NJ 08648.

Abstract

Suppose n identical items are simultaneously put into service and they operate independently until failure. The reliability at time t $(t > 0)$ is defined as $R(t) = Pr\ (X \leq t)$. Let $X_{1,n} \leq X_{2,n} \leq \cdots \leq X_{k,n}$ $(k \leq n)$ be the first k failure times. For several distributions various estimates of $R(t)$ are considered and their characterization problems are discussed based on these estimates.

Title : Approximate Analysis of Exponential Queueing Networks with Blocking.

Authors : Tayfur Altiok
Industrial Engineering Department
Rutgers University
Piscataway, NJ 08854

Harry G. Perros
Computer Science Department
North Carolina State University
Raleigh, NC 27695

Abstract:

An approximation procedure is developed for the analysis of open exponential queueing networks consisting of arbitrarily linked single server finite queues. The procedure decomposes the network into individual queues with revised arrival and service processes. The effect of blocking is incorporated into the model with the use of phase-type structures for the effective service time distributions. The steady-state marginal probability distribution of the number at each queue is obtained with an acceptible error level. The approximation procedure was validated using exact and simulation data.

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c/o Dr. A. Makowski
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College Park, MD 20742

Martingale Arguments for Stability:

The Two Queues Network Case.

Direct arguments based on the regularity of certain stopping times for exponential martingales are used to analyze discrete time, homogeneous random walks in the quarter plane, representing a wide class of two queues networks(joint arrivals, joint departures, bulk arrivals, coupling---) . We derive from these arguments:

- The stability condition (first established by MALYSHEV via the construction of a Lyapunov function).

- A general balance equation relating the distributions of idle periods in both queues.

- An analysis of busy periods by reduction to Boundary Value Problems.

STATISTICAL FORECASTING FOR STOCHASTIC PROCESSES

by

I. V. BASAWA

Department of Statistics, La Trobe University

Melbourne, Australia.

Abstract

Large sample properties of prediction errors when the parameters are estimated are discussed for a general class of stochastic processes. While both stationary and nonstationary processes are considered the nonstationary case is emphasised. The results are then applied to branching processes, and explosive growth curve models. New tests of goodness of fit based on the prediction errors are developed. The concept of robust prediction is also considered briefly.

Tests of Hypotheses in Queueing Systems

by

U. Narayan Bhat
Department of Statistics
Southern Methodist University
Dallas, Texas 75275

Abstract

The hypothesis testing problem in queueing systems can be approached as tests of hypotheses on constituent elements or as special cases of tests on general stochastic processes. In the first case information on the underlying stochastic process gets ignored and in the second case often times the procedures become too general to be generally accessible. In this paper we discuss a third approach in which specific properties of queueing systems are used to set up useful test statistics. Included among these are the sequential probability ratio tests for systems which exhibit some Markovian properties.

Computer Implementation of The Optimal Control

of Partially Observable Markov Processes

by

Shelby Brumelle and Hsien-Te Cheng
Faculty of Commerce
University of British Columbia
Vancouver, B.C.
CANADA

ABSTRACT

This study considers the implementation of Brumelle and Sawaki's algorithm for the optimal control of partially observable Markov process over an infinite horizon. The difficulties of the algorithm and how to handle them will be discussed.

AUTOVON RECONFIGURATION - A CASE STUDY

Dave Calabrese and Martin Fischer

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1860 Wienle Ave
Reston, VA 22090

ABSTRACT

In this paper we will discuss a study that was performed to reconfigure the 1984 CONUS AUTOVON. This network provides the military community with a circuit switching capability within CONUS. Every year a study is conducted to determine if the current network is cost effective and meeting the particular real world constraints at that time. The paper will focus on the methods used to gathered the data to perform the study, the computer algorithms used in developing the 1984 network and results of this particular study. Special emphasis will be placed on the real world constraints of the study and the techniques used to ensure these constraints are met.

Queueing Models, Block Hessenberg Matrices and
the Method of Neuts

by

Wei-Lu Cao
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Abstract

In the introduction to his book, Marcel Neuts argues eloquently for the numerical solution of models encountered in the study of practical queueing systems. He demonstrates that in many of the models of interest, the corresponding transition probability matrix has a block lower (or upper) Hessenberg form. Furthermore he shows how this structure may be exploited to obtain numerical results in a stable manner. In this talk we examine an alternative numerical approach. We note the restrictions which must be placed on the matrix for this method to be applicable are different from those used by Neuts so that there will be cases in which the first method is applicable while the second is not, and of course, vice versa. Some comparisons on the efficiency of the algorithms are also provided.

PROBABILISTIC MODELING OF COMPUTER SYSTEM AVAILABILITY

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Abstract: System availability is becoming an increasingly important factor in evaluating the behavior of commercial computer systems. This is due to the increased dependence of enterprises on continuously operating computer systems and to the emphasis on fault tolerant designs. Thus we expect availability modeling to be of increasing interest to computer system analysts and for performance models and availability models to be used to evaluate combined performance/availability (performability) measures. Since commercial computer systems are repairable, availability measures are of greater interest than reliability measures. Reliability measures are typically used to evaluate nonrepairable systems such as occur in military and aerospace applications.

We will discuss the types of probabilistic models and the analysis methods used to evaluate computer system availability. The state of the art will be summarized and problems that remain to be solved will be identified. We will consider both transient and steady state availability measures and for transient measures both expected values and distributions. The role of queueing networks in availability modeling will be discussed. We are developing a program package for system availability modeling and will discuss some of the issues confronted by the developers of such a package.

ABSTRACT

COMPUTATIONAL ANALYSIS OF SINGLE-SERVER BULK-ARRIVAL QUEUES

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Queueing theorists have presented, as solutions to many queueing models, probability generating functions in which state probabilities are expressed as functions of the roots of characteristic equations, evaluation of the roots in particular cases being left to the reader. Many users have complained that such solutions are very little solved. Some queueing theorists, rather than use Rouché's theorem to count roots and an equation-solver to find them, have developed new algorithms to solve queueing problems without explicit calculation of roots.

Pike and Barber used the root-finding method to discuss numerically some measures of efficiency for some bulk-arrival queues for small values of the parameters. Powell has recently shown that in many bulk service queues arising in transportation models, characteristic equations can be solved even when the number of roots to be found is large. He further states that finding the initial probabilities of system length distributions creates no problem. An approximate method for finding the tail of the system length distributions in bulk service queues and many other results have been reported in a unified way by Chaudhry, Madill and Chaudhry. In the present paper we have slightly modified other authors' techniques, and have extended their work to cover a number of different bulk-arrival queues as well as non-bulk queues. Results are obtained for both high and low values of the traffic intensity, the batch size and of the number of phases in the Erlang distribution.

COMPUTATIONAL SOLUTIONS OF THE TRUNCATED MOMENT PROBLEM

Kun-Jen Chung and Matthew J. Sobel
College of Management
Georgia Institute of Technology
Atlanta, Georgia 30332

Let D be the set of d.f. whose first K moments (given) are the same as the first K moments of an unknown d.f. F and let x be a number. The TMP (truncated moment problem) is to find worst-case bounds for F(x) in D. We formulate a linear program whose solution solves the TMP when F has a known finite support set. A simulation led to the comparison of solutions of the TMP with other plausible approximations of F. The results may be applicable to semi-Markov processes with rewards and to queueing models.

NATURALLY OCCURRING REDUNDANT RECURSIVE COMPUTATIONS

by

ROBERT B. COOPER
and
MARTIN K. SOLOMON

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Boca Raton, Florida 33431

Recently, programs whose execution causes an unacceptably large number of recursive calls on the same procedure with the same arguments, and the elimination of such redundant recursive calls, have received some attention in the computer science literature. In this paper we discuss two such problems that arose naturally in the context of computational probability, one of which was encountered by the authors in an application of queueing theory to the performance analysis of a database system. We consider the general utility of these elimination methods in performing probabilistic computations.

ANALYTICAL AND NUMERICAL TREATMENT OF A MULTI-STAGE CANCER MODEL

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(*) National Institutes of Health. Bethesda, MD 20205
(**) Dipartimento di Matematica. Università "La Sapienza". I-00184 Roma, Italy.

ABSTRACT

In the present paper we construct a continuous-time, discrete-"space", multistage model for tumor growth. The goal is to determine (analytically and/or numerically) the distribution of hitting times of significant thresholds (e.g. extinction of the tumor or, on the other hand, when does it reach a detectable size or when does it grow beyond treatment, etc.)

It is possible to simulate the model directly on a computer, and we present the results from a number of runs on a VAX minicomputer. On the other hand, we can look for analytical results, but only after performing a suitable limit to continuous "space". "Suitable" here means that time and/or "space" have to be scaled by a parameter after which we pass to the limit as the parameter diverges. We actually do this in two different ways, illustrating the ensuing analytical computations.

We emphasize that the main difference in these two limits pertains to the evaluation of the fluctuations around the mean behavior. Experimental data are extremely scarce in this respect, however we feel that interesting features could be overlooked if this essentaial randomness is systematically neglected.

Probability Theory vs. Simulation of Petroleum Potential in Play Analysis

by

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ABSTRACT

A petroleum play is a set of geologically similar prospects which may contain oil or gas. The purpose of play analysis is to provide probabilistic estimates of the volume of undiscovered oil and gas present in the play area, as well as probability distributions of these resources by pool size. The play analysis approach used by the U.S. Department of the Interior in the petroleum assessment of the National Petroleum Reserve in Alaska is based on Monte Carlo simulation techniques. Using the same geologic assumptions and same input data form, this paper describes an alternative approach based on probability theory. Probability theory enables the means and standard deviations of the petroleum potential distributions to be calculated exactly, that is, without sampling error. The computer program utilizing the probability theory approach operates thousands of times faster, allows for instantaneous feedback evaluation of geologic input data, and can be adapted to many microcomputers.

Probability Models for Processor Schedules in Real Time Applications - Numerical Solutions and Approximations

Bharat T. Doshi
AT&T Bell Laboratories

Abstract

We discuss a variety of probability models which have been used in the analysis of the processor schedules for real time applications. Some of these are frequently studied in the literature while the others involve nonstandard priority structures and performance objectives. We also discuss numerical methods used in solving these models and briefly comment on their general applicability.

Machine Interference in Manufacturing Cells

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ABSTRACT:

This research paper deals with the machine interference problem in manufacturing cells. The machines in the manufacturing cell are experiencing two types of stoppage which are to be served by a robot. The probability distributions of the stoppages are described by Weibull, lognormal and exponential distributions. We examine several service disciplines such as shortest distance travelled, shortest queue length, and FCFS. We then determine the optimal number of machines assigned to the robot under different operating conditions such that the total operating cost of the manufacturing cell is minimized.

A Monte Carlo Sampling Plan for Estimating Network Reliability

George S. Fishman
University of North Carolina at Chapel Hill

Abstract

Consider an acyclic undirected network $G = (V,E)$ with node set V and arc set E whose arcs are subject to random failure. Let s be a node in V and T a set of nodes in V such that $s \notin T$. This paper presents a relatively complete and comprehensive description of a general class of Monte Carlo sampling plans for estimating $g = g(s,T)$, the probability that s is connected to all nodes in T. The paper also provides procedures for implementing these plans. Each plan uses known lower and upper bounds $[B,A]$ on g to produce an estimator of g that has a smaller variance $(A-g)(g-B)/K$ than one obtains for crude Monte Carlo sampling ($B=0$, $A=1$) on K independent replications. The paper describes worst case bounds on samples sizes K, in terms of B and A, for meeting absolute and relative error criteria. It also gives the worst case bound on the amount of variance reduction that can be expected when compared with crude Monte Carlo sampling.

Computing the Reliability of the INCIA Avionics

Robert D. Foley
Virginia Polytechnic Institute and State University

The U.S. Air Force is developing integrated, communication, navigation, and identification avionics (ICNIA) for use in tactical aircraft. The ICNIA architecture is fault-tolerant; i.e., even though some components may have failed, ICNIA may be able to reconfigure itself in order to perform all of the critical avionics functions. Two different architectures are being developed, one at TRW and one at ITT.

Design engineers at both companies as well as Air Force personnel need to be able to evaluate the reliability of proposed designs. Due to the complexity of these systems, approximations had been used to estimate the reliability. We develop methods for computing the reliability and for obtaining upper and lower bounds on the mean time until system failure.

ABSTRACT

F.G. Foster
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The concept of stochastic flow will be investigated. In the light of this, some reflections on the elementary classical theory of queues from a new standpoint will be made.

J. Gani

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Abstract

"There is evidence to indicate that in some epidemics, the infection mechanism follows the law $\beta xy/(x+y)^{\alpha}$ rather than the more standard βxy. The consequences of this infection mechanism are worked out for both deterministic and stochastic epidemics."

Conditional Probability and Conditional Mean of a Multivariate Normal Distribution

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Abstract

Numerical methods are presented to find the conditional probability of a multivariate normal distribution over an n-dimensional rectangle. The extension of these techniques to obtain conditional means will be discussed as well as the possibilty of using other multivariate distributions. Finally, the results will be applied to a certain problem in Stochastic Optimization.

RANDOM PARAMETER STOCHASTIC PROCESSES:
SOME MODELS AND INFERENCE PROBLEMS

by

Donald Gaver[1]
Patricia Jacobs[1]
John Lehoczky[2]

ABSTRACT

Random parameter stochastic process models arise in many application areas including reliability and risk assessment, medicine and pharmacokinetics, and criminal justice modelling. The general model is that of a collection of stochastic processes governed by parameters. These parameters are random and are drawn from a distribution called the superpopulation. One wishes to use data gathered from a collection of these processes to estimate the individual parameters of each process and the unknown parameters of the superpopulation and to predict the future evolution of each individual process. Inference techniques will be developed, and the results will be applied to the application areas mentioned above.

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AN EFFICIENT DECOMPOSITION METHOD FOR THE APPROXIMATE EVALUATION OF TANDEM QUEUES WITH FINITE STORAGE SPACE AND BLOCKING

by Stanley B. Gershwin

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ABSTRACT

This paper presents a method for the evaluation of performance measures for a class of tandem queuing systems with finite buffers in which blocking and starvation are important phenomena. These systems are difficult to evaluate because of their large state spaces and because they may not be decomposed exactly. This decomposition approach is based on such system characteristics as conservation of flow. It offers a dramatic reduction of computational effort. Comparison with exact and simulation results indicate that it is very accurate.

"NUMERICAL PROBLEMS" WITH NON-LINEAR TECHNIQUES FOR STATISTICAL ESTIMATION OF DYNAMIC SYSTEMS

by

Paul Gilbert
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ABSTRACT

Most parameter estimation procedures for ARMA or state space representations of dynamic systems rely on a descent or hill-climbing algorithm. Proper convergence of these algorithms in turn relies on global properties of the objective function. On vector spaces the global property is usually described as some type of convexity. However, representations of dynamic systems are not naturally defined on vector spaces. The manifestation of this is the "ill-conditioning" problem which can arise from the selection of a canonical form. A generalization of convexity is introduced as a necessary condition and then used to show that least squared output error functions do not in general have this required global property.

A BIVARIATE CENTRAL LIMIT THEOREM FOR THE SAMPLE MEAN AND VARIANCE ESTIMATOR OF A REGENERATIVE PROCESS

by

Peter W. Glynn
University of Wisconsin
and
Donald L. Iglehart
Stanford University

ABSTRACT

Let $\mathbf{X} = \{X(t) : t \geq 0\}$ be a regenerative process with state space E and f a real-valued function on E. We denote the sample mean of $f(X(\cdot))$ by $r_t(f)$:

$$r_t(f) = \frac{1}{t}\int_0^t f(X(s))\,ds.$$

Under quite general conditions $r_t(f) \to r(f)$ a.s. and $t^{1/2}[r_t(f) - r(f)] \Rightarrow N(0,\sigma^2(f))$. The regenerative method for simulation analysis provides a simple way to construct a strongly consistent point estimator for $\sigma^2(f)$. Let $v_t^2(f)$ be that estimator based on a simulation to time t. In this paper we show that as $t \to \infty$

$$t^{1/2}\left[\begin{pmatrix} r_t(f) \\ v_t^2(f) \end{pmatrix} - \begin{pmatrix} r(f) \\ \sigma^2(f) \end{pmatrix}\right] \Rightarrow N(0,\Sigma).$$

A similar result holds with $v_t^2(f)$ replaced with $v_t(f)$. Explicit formulas are given for calculating the elements of Σ. Contrary to the common folklore, the variance of $v_t(f)$ is not necessarily minimized by using for the return state the regenerative state with the shortest expected cycle length.

TITLE: Gradient Estimation for Generalized Semi-Markov Processes

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ABSTRACT:

For each θ in some open set Λ of R^d, let $X(\theta) = \{X(t,\theta):t \geq 0\}$ be a stochastic process associated with θ. For a given real-valued "performance functional" f, let $r(\theta) = Ef(\theta,X(\theta))$. In this talk, we will discuss Monte Carlo methods for estimating the gradient $\nabla r(\theta)$, in the case that $X(\theta)$ is a generalized semi-Markov process. Two general families of algorithms will be presented, one of which is based on recent work of Ho and Suri. Applications to optimization and sensitivity analysis will be indicated.

Amrit L. Goel
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Stochastic Models for Software Reliability Modelling: A Critical Assessment

Several modelling approaches have been proposed during the past 13 years to quantity a multidimensional quality attribute, usually called software reliability. In this talk we provide a brief survey of the field, comment on the applicability of the models during various testing stages, provide some helpful hints on the selection and use of a model and discuss some problems with such approaches. We also briefly describe a new method for a user-oriented measure of software reliability based on a testing approach, which we call error-specific testing, and the use of possibility theory.

Winfried Grassmann
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Is this an M/M/c queue ?

Abstract

In this paper, we consider an G/G/c queueing system with known arrival rates and service rates, and we want to test the hypothesis that this queue is in fact an M/M/c queue in equilibrium. For this purpose, we calculate the average of the actual line length as it is observed from time 0 to time T. Since this average is asymptotically normal, we only need the true variance of this average to test our hypothesis. A formula to claculate this variance is derived in the paper, and its applications for testing hypotheses and contructing confidence intervals are given. Generalizations of this method to other Markovian queueing systems are also discussed.

THE G-SPECTRAL ESTIMATOR

by
Henry L. Gray
Department of Statistics
Southern Methodist University

ABSTRACT

In this paper a modified definition of the G-spectral estimator is given. It is shown that the resulting estimator is a method of moments ARMA spectral estimator which does not require an estimate of the moving average parameters. As a result, a new formula for the power spectrum of an ARMA process is given which does not explicitly involve the MA parameters. This formula then leads to a closed form expression for the MA parameters and their corresponding moment estimators.

Key Words: ARMA, G-spectral estimator, method of moments,
S-arrays

Alternative Realities: Changing Views of the Validity of a Queueing Model of Patrol Car Operations

Linda Green
Peter Kolesar
Columbia University

ABSTRACT

We describe the development, use, and subsequent empirical research on a queueing model of police patrol car operations and how under changing circumstances our views of the model's validity were radically altered. As the model's developers, enchanted with our own creation, we were at first its ardent champions. When management proposed a large scale implementation without further testing, we became the model's chief critics. Our follow-up empirical study lead us to an intermediate position. Among the validity issues we discuss are: scientific validity vs. managerial validity; validity of a model of a loosely managed system in which human behavior is central; and validity on the micro vs. macro scale.

ABSTRACT

Probability Models for Geographic Data Bases

by

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As with many other disciplines, the last few decades has brought a rapid metamorphosis in the field of cartography. That evolution has changed the main product of cartography, namely hard copy maps, to a soft product, namely a digital geographic data base. Those data bases are called upon to meet a plethora of different needs. They are used to draw maps from multiple points of view and in multiple scales, to build and analyze geographic images, to support the functioning of navigation and guidance systems, and to be a reference from which demographic and other data collection is accomplished.

The requirements for these very different tasks place different demands for quality and accuracy on the digital data. Even more important, the measures of quality used by cartographers for decades before the current age may not be relevant in a digital environment. The inherent uncertainty in the grographic data due to imprecise instruments and the inaccessibility of some areas suggests the need for stochastic models of analysis. It is from these models that one can hope to extract useful measures of quality and accuracy for a digital geographic data base.

This paper gives a brief statement of the problem and outlines some of the useful approaches. Approaches discussed include the introduction of spatial stochastic processes, pattern and image analysis, and statistical procedures.

As an example of how new measures can be applied, we also present the results of an accuracy analysis for a specific digital data base using the "kappa" statistic. This procedure which was originally developed for use in Biostatistics proved to be very useful for cartographic analysis. We include some background for the kappa statistic and some computer implementation issues in addition to the statistical results.

The Shortest Queue Problem

Shlomo Halfin

Bell Communications Research

ABSTRACT

A Poisson stream of customers arrives at a service center which consists of two single-server queues in parallel. The service times of the customers are exponentially distributed, and both servers serve at the same rate. Arriving customers join the shortest of the two queues, with ties broken in any plausible manner. No jockeying between the queues is allowed. Employing linear programming techniques, we calculate bounds for the probability distribution of the number of customers in the system, and its expected value in equilibrium. The bounds are asymptotically tight in heavy traffic.

Abstract: Martingale Methods and Stochastic Calculus in Clinical Trials.

David P. Harrington

This talk will explore the interaction between a very applied area (Biostatistics) and a considerably more abstract area (martingale theory and stochastic integrals). We will illustrate how the routine use of martingale methods provides a rigorous and intuitive tool for studying important questions that arisein the asymptotic theory of censored data rank test statistics. Such procedures are frequently used with data that are gathered in long term clinical trials. Specific applications will be given to the problem of combining dependent tests in a clinical trial and to sequential designs.

Title: A Stochastic Modeler's Workstation

Speakers: P. Heidelberger
R. Nelson
P. D. Welch
IBM T.J. Watson Research Center
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Abstract:

This paper will first describe the application of an interactive queueing network analyzer and an interactive graphics system to the analysis of a multi-microprocessor computer system. The application of these tools greatly increased the productivity of the modelers and resulted in insights which would have otherwise been difficult, if not impossible, to obtain. With this experience as background the paper will then discuss desirable features of computer workstations for stochastic modelers and the extent to which such workstations are likely to become an integral part of their everyday work.

Abstract

RISK PROFILES FOR SOME HIGH-CONSEQUENCE EVENTS; COMPUTATIONAL ASPECTS

David I. Heimann and Theodore S. Glickman

Risk profiles for events with low but significant probabilities of severe consequences, such as toxic chemical accidents, are often difficult to obtain. However, in some cases such profiles can be found through the combination of intermediate probability expressions. This paper describes a technique to obtain such risk profiles, with emphasis on addressing the considerations necessary to carry out the actual computations. Among such considerations are lack of complete knowledge of some of the input probability density functions, non-trivial underflow problems, and the necessity for an *a priori* starting point for the key iterative procedure. Techniques are also presented to directly obtain the means and variances of the risk profiles, without first computing the risk profiles themselves.

Asymptotic Marginal Independence in Large Networks of Loss Systems

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ABSTRACT

Network models in which each node is a loss system frequently arise in telephony. Models with several hundred nodes are common. Suppose a customer requires a server from each of several nodes. It would be convenient if the probability that the required servers are all free were approximately a product, where each term is the probability a required node has a free server. In this paper we present some theorems to support this approximation. Most of the theorems are restricted to nodes with one server. Some of the difficulties in analyzing nodes with multiple servers will be described.

AGGREGATION AND PERTURBATION ANALYSIS OF QUEUEING NETWORKS AND MANUFACTURING SYSTEMS

by

Y. C. Ho

and

P. Q. Yang*

Division of Applied Sciences

Harvard University

Abstract

This talk will show that the computation of sensitivities of performance measure with respect to system parameters in general queueing network can be considerably facilitated by the use of the newly developed perturbation analysis technique in conjunction with the generalization of the idea of Norton's theorem for queueing networks. Applications and results to manufacturing systems will be shown and discussed.

*On leave from Shanghai Jiao-Tong University, China.

PROBABILISTIC ANALYSIS OF COMBAT MODELS

by

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ABSTRACT

The recent work on deterministic and stochastic combat models is reviewed. The simplest stochastic combat model, in which the attrition rates of combatants depend on the numbers surviving during the combat, is considered as a Markov process. The method avoids the tedious inversion of Laplace transforms. Various characteristics of the system dynamics are evaluated and expressed in explicit form easy for computation. The results are extended to more complicated attrition functions and some approximate results are presented.

OPTIMIZATION AND PERFORMANCE EVALUATION PROBLEMS

ARISING IN PARALLELIZATION OF PARTICLE PHYSICS PROGRAMS

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P.Mussi : INRIA, B.P.105, 78153 Le Chesnay CEDEX, FRANCE.

Abstract

Particle Physics Experiments Simulations (e.g. by Monte-Carlo methods) require an ever increasing computational power, which cannot be provided by classical sequential computers. Many of these algorithms exhibit a large amount of parallelism, but are unfortunately non vectorizable, thus needing specialized parallel architectures.

In this paper, we use queueing theory methods to solve optimization problems arising in the implementation of particle physics programs, on a specialized parallel architecture (OPSILA) developped by LASSY* in collaboration with SINTRA-ALCATEL. The programs studied are those currently being used in CERN. Here we present a performance evaluation of the system and an analysis of the speedup obtained by such architectures.

Keywords : Simulation, Parallelism, Performance Evaluation.

LASSY* : Laboratoire d'Analyse des Signaux et Systèmes, Université de NICE.

Decomposition Approximation of Queueing Network Control Models with Tree Structures

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We devise a decomposition approximation method for a general branching queueing network with service controlling. The decomposition method which reduces and simplifies computation routines considerably results from the sufficient conditions for the monotone optimal control policies in induction arguments. We first isolate each branch of queues as a subsystem and then link the branches through branching nodes to obtain the optimal control policies for the whole system of network. The numerical results for a wide class of cost structures show that the suboptimal control policies from the decomposed problem are acceptably close to the optimal ones for the original global problem.

NORMAL RANDOM VARIATE GENERATION

Voratas Kachitvichyanulul
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ABSTRACT

An acceptance/rejection algorith is developed for sampling from the normal distribution. Compared with selected competitive algorithms in terms of execution speed, memory requirement, and lines of code, the algorithm is competitive with the fastest FORTRAN level algorithm but required only half the memory and can be implemented in only one-third the number of lines of code.

A STATISTICAL QUALITY CONTROL SYSTEM FOR THE ANALYSIS OF ELECTRO-MECHANICAL WAVEFORMS

Frank Kaminsky, Ph.D.
David Sonderman, Ph.D.

Abstract

This paper discusses the results of a research project to develop a statistical description of the force vs. displacement curve (a tracing) from a trigger pull of a major gun manufacturer's standard police revolver. The statistical description of a tracing is then used as a basis to develop a quality control sampling plan for identification of revolvers that may be defective. The basic data set for the statistical analysis was provided by the manufacturer and consisted of the tracings from 94 revolvers that were considered by the manufacturer to be typical of the production process that was in a state of statistical control. The complete tracing consists of one single-action pull (a first spike), followed by six double action pulls (six distinct waveforms).

A second data set was also provided by the manufacturer to use as basis for a statistical analysis of the variability that could be attributed to the measuring apparatus. This apparatus consisted of an electro-mechanical system that measured force vs. displacement and then transmitted the data to a personal computer. The second data set consisted of duplicate tracings from each of 10 revolvers. In the generation of this data set a second tracing from a revolver was produced by physically removing the revolver from the electro-mechanical apparatus and reinserting the revolver in the apparatus for a second trial which began with the same charge cylinder as the first trial. A statistical comparison was then conducted to determine the variability between duplicate tracings. Upon completion of the statistical analyses, the manufacturer provided the tracings from 10 revolvers which in some cases were judged to be defective. The statistical quality control plan was tested, with good results, using this third data set.

STATISTICAL INFERENCE FOR RANDOM FIELDS BASED ON POISSON SAMPLES

Alan F. Karr
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Abstract

Let $Y = \{Y(x): x \in \mathbb{R}^d\}$ be a random field (multiparameter stochastic process) on d-dimensional Euclidean space and let N be a Poisson process on $\mathbb{R}^d$, independent of Y, with points X_n. Suppose that rather than complete observations of Y one knows only the values of Y at the points of N, i.e., the <u>Poisson samples</u> $Y(X_n)$. We describe techniques for estimation of the mean and covariance function of Y under the stipulation that Y and N are both stationary; our estimators are consistent and asymptotically normal as the Poisson sample process is observed over increasingly large compact, convex sets. We also examine <u>state estimation</u>, the optimal recovery of unobserved values of Y, but only in the context of linear state estimators.

REAL WORLD ISSUES IN PROBABILITY MODELLING

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When a complex system of engineering or operations interest is modelled, conflicting demands are often imposed on the analyst. The basic conflict is between the need to represent intrinsic system complexity adequately and the need for answers of practical value.

To meet practical needs when analytical tools fail, algorithmic procedures and simulation techniques have been developed. The numerical and graphic results obtained, however, are not always satisfying or complete. Neither numerical methods nor analysis can stand alone. Each mode must be backed up by the other whenever possible.

Certain structure of striking simplicity arises in simple settings. This structure is revealed by complex plane methods and defies easy probabilistic interpretation. Such structural insight then provides the basis for numerical evaluation.

For most complex real world systems of interest, analytical resources are scarce. Dynamic behavior is much less accessible than steady state behavior, and the latter must provide the few insights available. For many information systems and telecommunication systems, however, service demand rate changes with time. To trust steady state behavior as an approximation, the system relaxation time is needed. When the system load is high and demand changes rapidly, steady state information may be worthless. A brief summary of the notion of relaxation time and an outline of related ideas and methods will be given.

* * *

Comparison of Inference Techniques for Markov Processes Estimated from Micro vs. Macro Data

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W. David Kelton
Department of Industrial and Operations Engineering
The University of Michigan
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Abstract

We estimate the parameters of a Markov chain model using two types of simulated data: micro, or actual interstate transition counts, and macro aggregate frequency. We compare, by means of Monte Carlo experiments, the power for micro likelihood ratio tests with their macro counterparts, developed previously by the authors to complement standard least-squares point estimates. We consider five specific null hypotheses, including parameter stationarity, entity homogeneity, a zero-order process, a specified probability value, and equal diagonal probabilities. The results from these micro-macro comparisons should indicate whether micro panel data collection is justified over the use of simpler state frequency counts.

Speaker: John F. Kitchin
Quality Assurance Technology
Bell Communications Research, Inc.

Title: Resolving Regenerative Stochastic Models
To Determine Limiting State Probabilities

ABSTRACT

A method is presented for resolving a continuous time, finite state regenerative stochastic model into a time-homogeneous (T-H) Markov model equivalent for determining limiting state probabilities. The method allies the regeneration point, Erlang, and supplementary variable methods of analyzing non-Markovian processes in an approach that produces exact results for all states without significantly increasing the size of the state space. An immediate application for the method is in predicting the steady-state availability of complex, fault-tolerant systems with non-exponential fault detection and repair times. Resolving to T-H Markov models is an attractive solution to the "non-exponential problem" since one need only preprocess input to existing automated (Markov) reliability prediction procedures rather than write new ones.

UNFINISHED WORK IN M/G/1 AND ITS OMNI-TRANSFORM

by Martin Krakowski

The process "unfinished work" in M/G/1 is effectively summarized by (A):

$$E\psi(w) = (1-\rho)\psi(0) + \rho E\psi(w+r) \tag{A}$$

where $\psi(\ )$ is an arbitrary "well-behaved" function and r is the residual time of the service time x; r and x are related through the renewal equation (B):

$$E\psi(x) = \psi(0) + Ex \cdot E\psi'(r) \tag{B}$$

where, like in (A), $\psi(\ )$ is an arbitrary "well-behaved" function.

We refer to $E\psi(Y)$ as the omni-transform of Y and to equations typified by (A) and (B) as omni-equations. The omni-transform (or functional) owes its flexibility to the arbitrariness of $\psi(\ )$, and its ease of handling to the simplicity when applied to sums and mixtures of random variables.

From (A) we get the moments of w by putting $\psi(w) = w^k$; the Laplace transform of w by putting $\psi(w) = e^{-sw}$; and the convolution equation (C) for the distribution of w by putting $\psi(w) = 1$ for $w \geq t$ and $\psi(w) = 0$ otherwise:

$$\Pr(w \leq t) = (1-\rho) + \rho \Pr(w+r \leq t) \tag{C}$$

a result equivalent to the Takacs integrodifferential equation. Using repeatedly the so-called shift property of omni-equations, (C) can be solved by representing the distribution of w as an infinite series of convolutions:

$$\Pr(w \leq t) = (1-\rho) + (1-\rho)\rho \Pr(r_1 \leq t) + (1-\rho)\rho^2 \Pr(r_1 + r_2 \leq t) + \cdots \tag{D}$$

where the r_i are a set of independent random variables, each distributed like r. Equation (D) is equivalent to a theorem of Beneš.

The omni-calculus has been also applied to the analysis of the busy period in M/G/1, to Markov and semi-Markov processes, to branching processes, to the theory of runs, and to the theory of mixtures of distributions.

Abstract

Shortest Paths in Markov Networks

by

V.G. Kulkarni

Curriculum in Operations Research
and System Analysis

This paper investigates the shortest path problem in Markov networks, i.e., networks with independent and exponentially distributed arc lengths. The problem is analysed by constructing a continuous time Markov chain with a single absorbing state such that the time until absorption in this state is equal to the length of the shortest path in the network. The state space of the Markov chain is identified with the set of minimal cuts in the network and the generator matrix of the chain is shown to be upper triangular. Simple and computationally stable algorithms are developed to compute the distribution and moments of the length of the shortest path. Algorithms are also developed for computing the probability that a given path is the shortest path in the network. Conditional quantities, e.g. the length of a path given that it is the shortest, are discussed. Computational experience is documented. The algorithms presented here suggest efficient simulation algorithms for the non-Markovian networks.

On Insensitive Bounds and Numerical Results for the Call Congestion in Tandem Queues

By Bernard F. Lamond and Nico Van Dijk
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ABSTRACT

We investigate a potential method for providing bounds on stationary characteristics in queueing systems by applying it to the call congestion in tandem queues with finite buffers. Moreover, a numerical computation of the call congestion is analyzed for the exponential case.

The bounding method is based on comparing the original system with modified systems exhibiting the Job-Local-Balance (JLB) property. This property implies that the stationary probabilities have a product form and are insensitive to the service time distributions up to their means. By proving that the modified systems provide lower and upper bounds we thus obtain an insensitive bounding method.

Numerical results, given for a wide range of system parameters, show an accuracy of the bounding method varying from about 0 to 25%. Because of the product form, the numerical values of those bounds are obtained directly.

A GENERAL MODEL FOR LIFETIMES

Larry Leemis
University of Oklahoma

There has been an increased emphasis in industry on components and systems with high reliability. Probabilistic models for lifetimes in the literature have analyzed elements (such as system structure, risks or environment) of the modeling problem, rather than incorporating all of these elements into a single model. This paper presents a general lifetime model and illustrates its usefulness.

NON-NORMAL TIME SERIES: Modelling, simulation and residual analysis

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ABSTRACT

This talk considers nonlinear, non-normal time series whose second order autocorrelations satisfy autoregressive Yule-Walker equations. The usual linear residuals are then uncorrelated, but not independent, as would be the case for linear autoregressive processes. Two such types of nonlinear model are treated in some detail: marginally specified random coefficient autoregressions and multiplicative autoregressions. The proposed residual analysis involves crosscorrelation of the usual linear residuals and their squares. An extended analysis is obtained by considering reversed residuals. In applications these residual analyses require only standard statitical calculations, and extend rather than replace the usual second order analysis.

ALGORITHMS FOR A WIDE CLASS OF GI/G/1 QUEUES

Speaker: David M. Lucantoni, AT&T Bell Laboratories

ABSTRACT

In the matrix-analytic, algorithmic solution of a number of queueing models involving phase type distributions, the central item to compute is the entrywise minimal nonnegative solution of a non-linear matrix equation of the form $R = \sum_{n=0}^{\infty} R^n A_n$ or $G = \sum_{n=0}^{\infty} A_n G^n$. The matrices A_n are obtained as the integral with respect to a distribution function of a set of matrices $P(n,t)$ which satisfy an infinite system of differential difference equations. Examples of such models are the special cases of the *GI/G/1* queue such as *GI/PH/1* and *PH/G/1*, which respectively correspond to the *GI/G/1* queue where the service time or interarrival time are phase type random variables.

We discuss an efficient scheme to compute the solution of these non-linear matrix equations without computing and storing the matrices $P(n,t)$ or the matrix sequence A_n. The algorithm presented requires a small number of matrices to be stored, yields a stable recursive scheme involving only nonnegative matrices, and is seen to perform well over a wide range of examples we have tested. The results here constitute a set of major simplifications in the algorithmic approach to these models and extend the realm of implementability of the matrix analytic techniques even for problems of large dimensionality. The analysis presented here also carries over to the multi-server queue with phase type services.

An Extension of the M/G/1 Heavy Traffic Approximation

William G. Marchal
The University of Toledo

Abstract

Numerical evaluation of waiting time distributions for M/G/1 systems is somewhat difficult. This paper examines a simple variation of the heavy traffic formula which may be useful at modest levels of traffic intensity. One can justify the heavy traffic approximation by expressing the Laplace transform of the service time distribution as a Maclaurin series and then truncating to three terms. The spectrum factorization and inversion leads in a straightforward fashion to the heavy traffic approximation.

If one carrys two additional terms from the Maclaurin series, the characteristic equation is a cubic with at least one real negative root in a closed interval. Hence it appears we have an easy way to extend the heavy traffic formula to cases where the traffic is not so heavy. This paper studies the quality of this approximation and includes some numerical evaluation based on data actually encountered.

A QUASI-BAYESIAN CONJECTURE

By

John H. McCray

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ABSTRACT

This paper presents a procedure for obtaining an approximate posterior probability mass function on the expected value of items in a population from a random sample given any prior probability distribution on the expected value. Several examples are presented and compared with results using the central limit theorem. These comparisons suggest that the proposed conjecture presents a useful alternative to the central limit theorem for evaluating results from a random sample.

On the Sojourn Time At A FCFS Node In A Product Form Queueing Network

James McKenna
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ABSTRACT

In this talk I will present a new method for calculating the probability distribution of the sojourn time of a customer at a single, m-server, FCFS node in a closed, product form queueing network. The method, which is based on previous work of McKenna and Mitra (1,2,3), is particularly well adapted to networks with a large number of nodes and customers.

For some time now, general expressions have been known for the probability distribution of the sojourn time of a customer at a single FCFS node in a product form network (4). If the network is open, the calculation is simple. If the network is closed or mixed, the calculation is more complicated. Recently, Heffes (5) has derived recurrence relations for calculating the probability distribution of the sojourn time at a single server FCFS node in a closed or mixed product form network.

In this talk I will show that the integral representation of the partition function, derived by McKenna and Mitra, can be used to derive integral representations of the probability distribution of the sojourn time of a customer at an m-server, FCFS node in a closed or mixed product form queueing network. Associated with the network is a parameter N which reflects in a natural way the size of the network. Asymptotic expansions of these integrals exist in powers of 1/N, and provide a means of calculating the distribution functions for large networks.

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A Statistical Procedure for Fitting
Markov - modulated Poisson Processes

Kathleen S. Meier

A Markov - modulated Poisson process (MMPP) is a Poisson process whose rate varies according to an irreducible m-state Markov chain. The MMPP is used in many applications, notably in communications modeling, to describe point processes with fluctuating arrival rates. A statistical procedure is developed for fitting the MMPP. It is illustrated for processes having two arrival rates modulated by an alternating exponential renewal process. The performance is evaluated within the context of queueing theory where such processes most often arise and is found to be highly satisfactory.

The Transient Output for a Series of $M/M/1/\infty$ Queues - Invariance Under Permutations of the Arrival Rate and the Service Rates

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M. Rosenshine
C. D. Pegden

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ABSTRACT

The order in which servers are placed in serial queueing systems is thought to affect the transient output distribution from the system. In a theoretical study, Rosenshine, Pegden, and Hubbard(1) have shown this postulate to be incorrect for two servers in series when there is ample storage space between the servers and there is always a customer ready to enter service the moment the first server becomes idle. This paper deals with the same type of system with three servers in series. The analysis is performed by simulation of the three-servers-in-series system for all possible permutations of the three servers and for several different service distributions. In all cases the order of the servers has no observable effect on the transient output distribution of customers.

A test for shifts in the distribution based

on the locations of the extremes.

by

Yashaswini Mittal.

Virginia Tech, Blacksburg, VA 24061.

short title: A test for shifts.

Abstract: For a sample in which the observations may be mildly dependent, a test is given for the null hypothesis of no change vs. the alternative of d unknown points at which unknown amounts of shifts in the distribution have occurred. The test is based on the asymptotic distribution of the normalized locations of the extremes and thus is distribution free. Estimates of the points at which the shifts occur are given. A multistage procedure is suggested. The asymptotic properties of one-stage testing and estimation are studied. Some Monte Carlo results are presented for both a one stage and a two stage procedure.

PROFILE CURVES OF QUEUES

Marcel F. Neuts
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For the PH/G/1 queue and for many other stochastic models with an embedded Markov renewal process of M/G/1 type, there is interest in augmenting the state description to keep track also of the number of services already completed during the current busy period. The stationary distributions of the resulting embedded process are algorithmically tractable.

By computing, for example, sufficiently high percentiles of the queue length distribution at the end of the j-th, $j \geq 1$, services of busy periods, we obtain a first profile curve. For traffic intensities not exceeding the given values ρ, these percentiles define a region likely to contain most paths of the queue length during a typical busy period. By determining the profile curves for various traffic intensities and for different input and service time characteristics, we may elucidate many features of the behavior of the queue. For a queue with fixed design characteristics, the profile curves may play a role similar to the control limits in process control. Further profile curves may be defined for the queue length at other epochs, as well as for the waiting times.

Clocked Operating Systems, Queues, and Almost Phase Type Distribution

Teunis J. Ott

Bell Communications Research, Inc.

The concept of a clocked operating system is introduced and its importance in communications systems is explained. A queueing model for such a clocked operating system is established. This is a single server queueing system with two independent arrival streams: a "D/G" and an "M/G" stream. A number of techniques exist for finding information about this model. One which I have developed recently is based on the following:

Theorem: Let the "D/G" customers arrive at epochs kT (k integer) and have a service time distribution with Laplace Stieltjes Transform (LST) $\phi(s)$. Let the "M/G" customers arrive according to a Poisson process with intensity λ and let their service times have LST $\psi(s)$. Let $V(t)$ denote the virtual waiting time process.

In this case, if $\phi(\cdot)$ and $\psi(\cdot)$ have the form ($0 \le x_o < T$, $\theta > 0$)

$$\phi(s) = e^{-sx_o} \sum_{k=o}^{\infty} p_k (1 + \frac{s}{\theta})^{-k} \quad , \tag{1}$$

$$\psi(s) = \sum_{k=o}^{\infty} q_k (1 + \frac{s}{\theta})^{-k} \quad , \tag{2}$$

$$p_k \ge 0, q_k \ge 0, \sum_{k=o}^{\infty} p_k = \sum_{k=o}^{\infty} q_k = 1 \quad , \tag{3}$$

then a numerically stable, quickly converging algorithm exists for computing the stationary distribution of $V(t)$, and (for example) there exist constants $(B_k)_{k=1}^{\infty}$, $B_k \ge 0$ for all k,

$$1 > B_1 \ge B_2 \ge \ldots, \lim_{k \to \infty} B_k = 0, \tag{4}$$

such that for the stationary distribution:

$$P\{V(t) > 0\} = \begin{cases} 1 & \text{for } 0 < t < x_o \\ \\ e^{-(\lambda - \theta)(t - x_o)} \sum_{k=1}^{\infty} B_k \frac{((\lambda+\theta)(t-x_o))^{k-1}}{(k-1)!} & \text{for } x_o < t < T. \end{cases} \tag{5}$$

These constants B_k are computed in the algorithm already mentioned. The algorithm will be discussed.

Distributions as in (2) I have baptized "almost phase type" distributions.

TIME SERIES MODEL IDENTIFICATION AND QUANTILE SPECTRAL ANALYSIS

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Abstract

This paper discusses relations between Quantile Data Analysis, time series spectral analysis, identification of the memory type of an observed time series, and identification of time domain models that fit an observed time series. An important diagnostic of memory is the index δ of regular variation of a spectral density; estimators for δ are discussed. The model identification procedures proposed are illustrated by analysis of long memory series simulated by Granger and Joyeux, and the airline model of Box and Jenkins.

Research supported in part by the Army Research Office and the Office of Naval Research.

A Multiple Threshold AR(1) Model

by

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Samuel W. Woolford
Worcester Polytechnic Institute
Worcester, Massachusetts
U.S.A.

K. S. Chan
H. Tong
Chinese University of Hong Kong
Hong Kong

Abstract

We consider the model $Z_t = \phi(0,k) + \phi(1,k)Z_{t-1} + a_t(k)$ whenever $r_{k-1} < Z_{t-1} \leq r_k$, $1 \leq k \leq \ell$, with $r_0 = -\infty$ and $r_\ell = \infty$. Here $\{\phi(i,k);\ i = 0, 1;\ 1 \leq k \leq \ell\}$ is a sequence of real constants, not necessarily equal, and, for $1 \leq k \leq \ell$, $\{a_t(k),\ t \geq 1\}$ is a sequence of i.i.d. random variables with mean 0 and with $\{a_t(k),\ t \geq 1\}$ independent of $\{a_t(j),\ t \geq 1\}$ for $j \neq k$. Necessary and sufficient conditions on the constants $\{\phi(i,k)\}$ are given for the stationarity of the process. Least squares estimators of the model parameters are derived and, under mild regularity conditions, are shown to be strongly consistent and asymptotically normal.

On the Ergodicity of Some Threshold AR(k) Processes

by

Joseph D. Petruccelli
and
Samuel W. Woolford

Department of Mathematical Sciences
Worcester Polytechnic Institute
Worcester, Massachusetts

Abstract

We consider the model $Z_t = \sum_{i=1}^{k} \phi(i,j) Z_{t-i} + a_t(j)$ when $[Z_{t-1}, Z_{t-2}, \ldots, Z_{t-k-1}]' \in R(j)$, where $\{R(j);\ 1 \le j \le \ell\}$ is a partition of $\mathbb{R}^k$, and for each $1 \le j \le \ell$, $\{a_t(j);\ t \ge 0\}$ are i.i.d. zero-mean random variables, having a strictly positive density. Sufficient conditions are obtained for this process to be transient. In addition, for a particular class of such models, necessary and sufficient conditions for ergodicity are obtained.

A POSTERIORI PROBABILITY OF ZERO DELAY FOR TRAFFIC DATA

by

Steve Pincus and Michael Saks
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West Long Branch, New Jersey

ABSTRACT

To accurately staff teams of servers, we analyze traffic data and model the data by an appropriate analytic model. Typically, we are given the following data on a half-hourly basis: number of servers, number of calls, average holding time per call, and (actual) average delay per call.

In the process of analyzing data from actual teams of servers, it seemed that there were unusually few half-hours with a zero average delay per call. We were interested in showing that these data cannot be explained by a typical and conservative theoretical model, in the following way. For each half hour, we computed the theoretical probability of zero delay. We then summed these probabilities over all half hours to calculate the expected number of half hours with zero delay. We compared this to the actual number of zero delay half hours, and showed that there was a large discrepancy.

We analyzed the theoretical probability of zero delay in two different ways. For some values of the number of calls and the number of servers, we computed a polynomial that gives the exact probability of zero delay as a function of the average holding time of the call. In other cases, we computed an approximate polynomial in which the coefficients are computed using a combination of simulation and analytic techniques.

We analyzed the problem as an a posteriori problem of computing the probability that there should have been no delay in a half hour given n calls, m servers, and a specified constant holding time.

The a posteriori probability of zero delay seems to be an unexplored version of a classical queueing theory problem. Both the constant holding time and constrained number of calls take the problem out of the realm of standard exponential assumptions. Nonetheless, we feel this is an interesting problem to consider, especially since it arises from actual data analysis.

From the viewpoint of exact analysis, we were able to find a general formula for the probability of zero delay in a number of cases. We used an intuitive measure-preserving transformation in some of the calculations, and believe that this technique can be used to generate further formulas for this problem. From the viewpoint of approximate analysis, we combined knowledge of the general answer form, first term behavior, and simulation to calculate general polynomials for the probability of zero delay.

CONTACT TIME DISTRIBUTION STUDIES IN CHEMICAL REACTORS USING PROBABILITY MODELING

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Department of Chemical Engineering
Coimbatore Institute of Technology, Coimbatore, India

ABSTRACT

In the present paper a generalised stochastic model for the contact time distribution of fluid-solid system is described. The stochastic approach is an unified one and it attempts to account directly for the random nature of the system. It describes both the steady state and time dependent behaviour of the system to any desired degree of approximation. The description and analytical structure of the model is very similar to those that have been considered by Krambeck et al (1967) in introducing the concept of stochastic mixing model for chemical reactor. The model is developed with the aid of random walk process for the passage of tagged particle through the system. When we consider the random passage of element through heterogenuous reactor system, the important properties of the contact element in the random passage is the contact time distribution where the contact time is defined as length of time a particle spends in the active part of the system during its passage.

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* Director, Krishna Industrial Corporation Ltd., Madras, India.

Telecommunications and Queues: Two Examples

Peter Purdue, University of Kentucky and
National Science Foundation

Peter Malpass, Contel Information Systems, Inc.

Abstract

Telecommunications systems are a source of many unusual queueing models. In this talk we discuss two such models. The first model arises in a study of the buffering process at a node that connects terminals to various processing sites. The second arises out of a local area network. Branching process and matrix-geometric methods are used to examine various system performance measures; numerical results are also discussed.

SOME STATISTICAL PROBLEMS IN RANDOM TRANSLATIONS

OF STOCHASTIC POINT PROCESSES

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Instituto Superior Tēcnico

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ABSTRACT:

A random translation of a marked point process is considered. The random translation is assumed to be dependent upon the mark through a certain function h(.). The main concern is to study the form of the function h(.) for different types of data. Complete identification and estimation are not possible, in general, but some interesting particular solutions are presented.

STATIONARY WAITING TIME IN

MULTI-SERVER QUEUES WITH PHASE TYPE SERVICE AND IN QBD PROCESSES

Speaker: V.Ramaswami, Bell Communications Research Inc.

ABSTRACT

The algorithm to compute the rate matrix in the matrix-geometric solution for the single server queue with phase type service, obtained recently by Lucantoni and Ramaswami, is generalized to the multiserver case. Exploiting the probabilistic interpretations of these, we show that the cdf of the stationary waiting time in the multi-server queue with (possibly heterogeneous) phase type servers as well as in queues which can be represented as quasi-birth-and-death processes is of the form $\sum_{n=0}^{\infty} d_n e^{-\theta t}(\theta t)^n/n!$ where θ is a positive number and d_n are certain probabilities. These constants are completely characterized in terms of the rate matrix, and can be computed by stable algorithms.

SOME ISSUES RELATED TO INTERPOLATION APPROXIMATIONS FOR QUEUEING SYSTEMS

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ABSTRACT

Interpolation approximations are available for a wide class of queueing systems which cannot be analyzed exactly. The approximation, which is an interpolation in the arrival rate, is based on exact limiting behavior in both light and heavy traffic. A heavy traffic limit theorem yields an expression for a normalized quantity of interest (e.g. n^{th} moment of stationary sojourn time). In light traffic, in addition to the limit, it is possible to obtain derivatives of the quantity of interest with respect to the arrival rate. The heavy traffic limit, light traffic limit and k derivatives uniquely determine a k+1 degree polynomial in the arrival rate, which we propose as an approximation to the normalized quantity of interest.

Due to the instability of queueing systems in heavy traffic, it is typically necessary to normalize the quantity of interest in order to obtain a finite heavy traffic limit. We have found that the accuracy of the approximation can be improved by utilizing additional information about the queueing system in the choice of the normalizer. Theoretical and experimental results are presented to aid the choice of the normalizer for queueing networks with arbitrary routing, general service times, and priorities.

The effort required to calculate derivatives, both symbolically and numerically, increases rapidly in the order of the derivative. We will describe several methods for numerical calculation of derivatives, including an application of the Monte-Carlo method. In addition, we will present some results which help to speedup the calculations.

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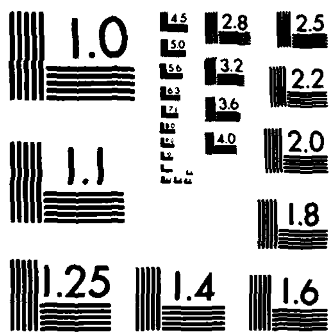

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

ON THE ANALYSIS AND SIMULATION OF INTEGRATED VOICE/DATA COMMUNICATION NETWORKS

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and
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We consider an integrated tandem transmission network where each link is represented by a multiserver service station. Voice calls, characterized by low arrival and service rates, can only be initiated when there are channels available on all links connecting the origin node to the destination node. When this is not possible the voice call is considered lost. Data packages have high arrival and service rates and have the ability to queue if all service channels are busy.

Under Markovian assumptions and first-come, first-served service discipline, the stationary probability vector for this model can be shown to have a modified matrix-geometric structure. However, due to the differences in the relative magnitudes of parameters relating to voice and data traffic the numerical procedures exhibit poor convergence characteristics. Similarly, the simulation approach to this problem requires excessively long computer runs to obtain accurate estimates for the system performance measures.

SOME ISSUES RELATED TO INTERPOLATION APPROXIMATIONS FOR QUEUEING SYSTEMS

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ABSTRACT

Interpolation approximations are available for a wide class of queueing systems which cannot be analyzed exactly. The approximation, which is an interpolation in the arrival rate, is based on exact limiting behavior in both light and heavy traffic. A heavy traffic limit theorem yields an expression for a normalized quantity of interest (e.g. n^{th} moment of stationary sojourn time). In light traffic, in addition to the limit, it is possible to obtain derivatives of the quantity of interest with respect to the arrival rate. The heavy traffic limit, light traffic limit and k derivatives uniquely determine a k+1 degree polynomial in the arrival rate, which we propose as an approximation to the normalized quantity of interest.

Due to the instability of queueing systems in heavy traffic, it is typically necessary to normalize the quantity of interest in order to obtain a finite heavy traffic limit. We have found that the accuracy of the approximation can be improved by utilizing additional information about the queueing system in the choice of the normalizer. Theoretical and experimental results are presented to aid the choice of the normalizer for queueing networks with arbitrary routing, general service times, and priorities.

The effort required to calculate derivatives, both symbolically and numerically, increases rapidly in the order of the derivative. We will describe several methods for numerical calculation of derivatives, including an application of the Monte-Carlo method. In addition, we will present some results which help to speedup the calculations.

Asymptotic Behavior of Maximum Queue Lengths

by

Richard F. Serfozo

Georgia Tech

In a stable M/M/1 queue, the maximum queue length M_n over n busy periods does not have an asymptotic distribution: there are no constants a_n, b_n such that the distribution of $M_n' = (M_n - a_n)/b_n$ converges to a nondegenerate limit as $n \to \infty$. We show that in order for M_n to have an asymptotic distribution, the traffic intensity ρ of the queue must also vary such that $\rho \to 1$ and $n \log(1-\rho) \to c$ as $n \to \infty$. And when $c=0$, $0<c<\infty$, and $c=\infty$, the respective asymptotic distribution is $\exp(-x^{-1})$, $\exp\{-c/(e^x-1)\}$ and $\exp(-e^{-x})$. The first and last distributions are two of the three classical extreme-value distributions. The middle distribution, which has not yet appeared in the literature, offers the best approximation for M_n even when ρ is not near one. We present similar results for M/G/1 and G/M/1 queues; this analysis is based on limits of complex integrals over varying contours.

Uniformization and hybrid simulation/analytic models of stochastic systems

by

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Abstract

We demonstrate the use of uniformization in the development of hybrid simulation/analytic models of stochastic systems under very general conditions. The variance of any estimator in a traditional simulation model is always larger than the variance of an associated estimator in the corresponding hybrid simulation/analytic model. Application of these results to renewal process and single server queueing systems will be illustrated with numerical results.

Key words: hybrid simulation/analytic models, uniformization, variance reduction, queues.

FRACTIONALLY DIFFERENCED MODELS FOR WATER QUALITY TIME SERIES

by

Wray Smith

This paper deals with the selection and evaluation of statistical techniques for use in modeling and forecasting of water quality time series. The focus will be on statistical concepts relevant to the analysis of flows and concentrations. A selection of time series procedures has been used for auditing water quality archival data, including the screening of data sets, correlation and spectrum calculations, and iterative model fitting. Included will be a summary of experience with analyzing archival data on the Niagara River and the use of a fractionally differenced model.

MATHEMATICAL MODELS USED TO SOLVE DESIGN, PLANNING, AND SCHEDULING PROBLEMS OF FLEXIBLE MANUFACTURING SYSTEMS

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The University of Michigan
Ann Arbor, Michigan

Rajan Suri
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ABSTRACT

Mathematical models are of late being used to analyze various design, planning, and operating issues associated with flexible manufacturing systems. This paper overviews these various models, with special emphasis on the queueing network models that are being developed for these purposes. We conclude by providing examples of which, and how, these models are currently being used by existing flexible manufacturing installations to help make decisions and to help operate the systems.

Stable Recursive Procedures for Numerical Computations in Markov Models

by

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Abstract

Recursive methods have been proposed for the numerical solution of equations arising in the analysis and control of Markov processes. Two examples are solving for the equilibrium probabilities in Markov processes with left-skip-free transition structure and solving for the expected cost or time to reach state zero in Markov processes with right-skip-free transition structure. We discuss conditions under which such recursive techniques are numerically stable and efficient, giving applications to descriptive and control models for queues.

Numerical Exploration of a Bivariate Lindley Process via the Bivariate Laguerre Transform.

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and
Masaaki Kijima

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University of Rochester

ABSTRACT

In a recent paper by Sumita and Kijima (1984), the bivariate Laguerre transform has been developed, which provides a systematic numerical tool for evaluating repeated combinations of bivariate continuum operations such as bivariate convolutions, marginal convolutions, double tail integration, partial differentiation and multiplication by bivariate polynomials. The formalism is an extension of the univariate Laguerre transform developed by Keilson, Nunn and Sumita (1979, 1981), using the product orthonormal basis generated from Laguerre functions. In this paper the power of the procedure is demonstrated by studying numerically a bivariate Lindley process arising from certain queueing systems. Various descriptive distributions reflecting transient behavior of the associated queueing system are explicitly evaluated via the bivariate Laguerre transform.

A VARIABLE BUFFER-SIZE MODEL AND ITS USE IN ANALYZING CLOSED QUEUEING NETWORKS WITH BLOCKING*

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ABSTRACT

We present a model which enables efficient analysis of certain types of closed queueing networks with blocking due to limited buffer spaces. The networks analyzed are those in which the limited buffers occur in tandem subnetworks. A new model, with variable buffer-size, is introduced as a conceptual tool to model part of a tandem network with blocking, using only product-form submodels. Using this model we iteratively solve for the whole network. The technique is illustrated first, for a simple system with tandem queues, and then for more complex systems. The method is compared with exact solutions or simulations, and found to be reasonably accurate. The method is easily implemented using standard software for closed queueing networks. Given the complexity of the blocking problem, our approach offers a simple and efficient alternative to exact analysis.

Key Words: Closed queueing networks, product form networks, blocking, buffer size, approximate analysis, performance modelling, performance prediction.

Version: September 1983

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Abstract for "Control Variate Estimators in the Analysis of Nonlinear Statistical Models" for the Third ORSA/TIMS Applied Probability Special Interest Meeting.

A control variate method is described to study the properties of the sampling distribution of nonlinear model parameter estimators. The sampling distribution of parameter estimators for nonlinear models with finite sample sizes is usually intractible, but provides useful information to the practitioner. These properties include the moments, covariances and variances, quantiles, and percentage points of the distribution. The standard approachs include asymptotic and series approximation, and Monte Carlo sampling.

The control variate method described here uses approximators as the control variates in Monte Carlo sampling. This reduces the variance of the Monte Carlo estimators without significantly increasing the effort needed to obtain the estimators. Approximators are readily available from the nonlinear model literature. A particular advantage of this approach is that the variance reduction is obtained without alteration of the sampling method, thus preserving the sampling distribution of the parameter estimators under study and permitting simultaneous determination of all properties of the sampling distribution.

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APPROXIMATING NONSTATIONARY QUEUEING MODELS

WITH PHASE DISTRIBUTIONS OF INTERARRIVAL AND SERVICE TIMES

by

Michael R. Taaffe
and
Kim Ong

Purdue University

ABSTRACT

This talk presents algorithms to accurately approximate the behavior of nonstationary finite capacity queueing systems that have time-dependent Phase distributions for inter-arrival times and time-dependent Phase distributions of service times. Phase distributions can take a variety of shapes from Deterministic to Exponential to approximately Normal, thus their use in constructing models of actual phenomena adds realism. Time dependent behavior of inter-arrival and service times is also more typical of real systems than the usual stationary assumptions. The approximations presented are very accurate and robust. The algorithms avoid the large set of differential-difference equations of the actual model by making use of a moment matching surrogate distribution approach. The state spaces of these complex models can be partitioned such that a small set of conditional moment differential equations and surrogate distributions provide solutions within 5% of the actual solutions. The talk will outline the algorithms and present numerical results.

Uncertainty estimation for
stochastic process parameters.

M.E. THOMPSON
University of Waterloo

When a simple Markov or semi-Markov model is fitted to a large set of data over several points in time, confidence intervals based on the asymptotic distribution of the maximum likelihood estimate are generally too narrow. Accordingly the estimated precision of forecasts is too optimistic. These problems arise not only because of inhomogeneities in the sample, but also because of time inhomogeneities in the parameter values themselves. In this paper some approaches to finding more realistic interval estimates and forecasts will be surveyed.

A Bootstrap Analysis of an Econometric Applicatio

of the Kalman Filter

Kent D. Wall
Dept. of Systems Engineering
University of Virginia

The bootstrap method is applied to an econometric model i certain unobserved variables have been estimated via the Kalma The inherent instability of the underlying model casts doubt o of inferences drawn from classical asymptotic distribution the the bootstrap offers an attractive alternative to such an appr The distributions obtained using the bootstrap shed new light original, more traditional statistical analysis.

Title: Approximations for the waiting time percentiles in the M/G/c queue.

Author: H.C. Tijms (co-author A.G. de Kok)

Address: Vrije Universiteit, Dept. of Actuarial Sciences and Econometrics,
De Boelelaan 1081, Amsterdam, The Netherlands.

Abstract

A simple but effective approximation for the waiting time percentiles in the multi-server queue with Poisson input and general service times will be presented. The approximation requires only the first two moments of the service time and is based on readily computed results for the special cases of exponential and deterministic services. The computations involve new asymptotic results for the waiting time distribution . Extensive numerical experiments will be reported.

OPEN-MODEL APPROXIMATIONS FOR CLOSED QUEUEING NETWORKS

by

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ABSTRACT

In an open queueing network, customers enter the network from outside, receive service at one or more service centers, and then depart. In a closed queueing network, customers neither enter nor leave the network; instead, a fixed number of customers circulate inside. For many applications, the closed model is much better because it realistically represents system constraints, but the closed model is analytically less tractable. As the closed network grows (in terms of the number of nodes, customers or customer classes), it becomes more and more difficult to analyze. However, as the closed network grows, the coupling often tends to decrease, so that it becomes appropriate to use a much more tractable open model.

Two ways to use an open model to approximate a closed model are: (1) make the expected population in the open model equal to the fixed population in the closed model, and (2) replace a bottleneck service center in the closed model by an external arrival process. Stochastic comparisons and limit theorems provide useful insight into these approximation schemes. In several cases, we have shown that the open-model approximations provide bounds for the closed model and are asymptotically correct as the network grows.

REFERENCE

Whitt, W. Open and Closed Models for Networks of Queues. *AT&T Bell Laboratories Technical Journal*, Volume 63, November 1984.

Response Surface Methodology as a Means for Efficient Data Storage and Retrieval

by

K. Preston White, Jr.

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Charlottesville, VA 22901

Abstract

Response surface methodology (RSM) is a synthesis of standard statistical techniques for developing parsimonious models from experimental or simulation data. Response surfaces typically are used to investigate the relationship of response variables to predictor variables in order to determine (1) the sensitivity of the response to changes in the predictor variables, or (2) the combination of predictor variables for which the response is optimized. In this presentation, we consider the issue of parsimony, explicitly, and the resulting *implications of* RSM for data storage and retrieval in large-scale design studies. We show that, when combined with an appropriate parameterization of the underlying process, RSM is a highly efficient means for capturing the essential summary results of multiple experiments or simulation runs.

Specifically, we show that if an adequate parameterization of a process can be achieved in p parameters, this parameterization permits the results of m experiments or simulation runs to be stored in a single array of dimension [m x (p+n)], where n is the the number of experimental treatments or simulation control variables. Through the application of RSM, these summary data can in turn be modeled by the coefficients of p polynomials in the experiment or simulation control variables. As a consequence of this two-step procedure, the results of the entire study can be summarized by a response surface, which can be stored in an array of dimension (p x 2q), where q is the maximum number of terms in any of the approximating polynomial regression equations.

The method described in this presentation is illustrated by an application of RSM in determining optimal passenger-vehicle designs for occupant crash protection. For the specific vehicle collision problem described, we show that the essential results of 128 crash simulations, consisting of a total of more that a million individual data elements, can be stored in a single array of dimension (2 x 34), with only 68 data elements. This array defines an approximate closed-form solution for the original simulation model and represents a reduction in data storage requirements of almost seven orders of magnitute. The method described here has been used with success in vehicle design optimization studies and is readily extended to other applications.

The Probabilistic Shortest Queue Routing

in Closed Networks of Queues

by

David D. Yao
Department of Industrial Engineering
and Operations Research
Columbia University
New York, New York 10027

ABSTRACT

Consider a closed network of queues with a set of stations, each having a limited local buffer. We develop a probabilistic shortest queue (PSQ) routing scheme, which routes jobs to the shortest queue with the highest probability. We prove that with the PSQ routing, the associated Markovian queue length process satisfies time reversibility and has a product-form equilibrium distribution. An algorithm is developed to efficiently compute solutions to the network. It is found that the PSQ routing can be a good approximation to the regular shortest queue routing under certain conditions, and is superior to the fixed-probability routing in terms of reducing blocking, increasing throughput and the utilization of local buffers. Applications to manufacturing and computer systems will be briefly discussed.

SOME ORDER RELATIONS IN JACKSON NETWORKS

by

David D. Yao

and

Sung Chul Kim

Department of Industrial Engineering
and Operations Research
Columbia University
New York, New York, 10027

ABSTRACT

The motivation of this study is to develop insight into the loading and the server-assignment policies in queueing network models of job shops. Two types of order relation, majorization and arrangement, are explored in open/closed networks of queues of the Jackson type. It can be shown that in the presence of these orderings, the throughput function (closed networks) and the cumulative density functions of the total number of jobs and some order statistics of queue lengths at the stations (open networks) are Schur convex/concave and arrangement increasing. As a consequence of these properties, loading and server-assignment policies can be compared based on the majorization and arrangement orderings. Implications of the results will be discussed.

SPEAKER LIST

PROFESSOR M. AHSANULLAH "CHAR OF DISTS BY USING ESTIMATES OF RELIABILITY"
DEPARTMENT OF DECISION SCI & COMPUTERS
RIDER COLLEGE
LAWRENCEVILLE, NJ 08648 SESSION NUMBER W92

PROFESSOR TAYFUR ALTIOK "APPROX ANALYSIS OF EXPO Q N/WS W/BLOCKING"
DEPARTMENT OF INDUSTRIAL ENGINEERING (JOINT WITH HARRY PERROS)
RUTGERS - THE STATE UNIVERSITY
PISCATAWAY, NJ 08854 SESSION NUMBER M71

PROFESSOR M.F. BACCELLI "MARTINGALE ARGUMENTS FOR STABILITY OF 2 QS"
C/O DR. A. MAKOWSKI
DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF MARYLAND
COLLEGE PARK, MD 20742 SESSION NUMBER T82

PROFESSOR ISHWAR V. BASAWA "STATISTICAL FORECASTING FOR STOCH PROCS"
DEPARTMENT OF STATISTICS
LATROBE UNIVERSITY
BUNDOORA, VICTORIA SESSION NUMBER M2T
AUSTRALIA 3083

PROFESSOR U.N. BHAT "TESTS OF HYPOTHESES IN QUEUEING SYSTEMS"
DEPARTMENT OF STATISTICS
SOUTHERN METHODIST UNIVERSITY
DALLAS, TX 75275 SESSION NUMBER M21

DR. LYLE D. BROEMELING
MATHEMATICAL SCIENCES DIVISION
OFFICE OF NAVAL RESEARCH
ARLINGTON, VA 22217 SESSION NUMBER TE1

DAVE CALABRESE "AUTOVON RECONFIGURATION - A CASE STUDY"
DEFENSE COMMUNICATION ENGINEERING CENTER (JOINT WITH M. FISCHER)
1860 WIEHLE AVENUE
RESTON, VA 22090 SESSION NUMBER W52

W.C. CARTER (SEE S.S. LAVENBERG)
T.J. WATSON RESEARCH CENTER
IBM
YORKTOWN HEIGHTS, NY 10598 SESSION NUMBER T32

PROFESSOR MOHAN L. CHAUDHRY "COMPUT ANAL OF SINGLE-SERV BULK-ARRIV QUEUES"
DEPT. OF MATHEMATICS & COMP SCI (JOINT WITH J.G.C. TEMPLETON & J.L. JAIN)
ROYAL MILITARY COLLEGE
KINGSTON, ONTARIO K7L 2W3, CANADA SESSION NUMBER T33

PROFESSOR HSIEN-TE CHENG "COMP IMPLEM OF THE OPT CONTROL OF PARTIALLY OBS.."
FACULTY OF COMMERCE (JOINT WITH SHELBY BRUMELLE)
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, B.C., CANADA SESSION NUMBER T81

PROFESSOR ROBERT B. COOPER "A NATURALLY OCCURRING REDUND RECURS COMPUT"
DEPARTMENT OF COMPUTER & INFORMATION SYSTEMS (JOINT WITH MARTIN SOLOMON)
FLORIDA ATLANTIC UNIVERSITY
BOCA RATON, FL 33431 SESSION NUMBER W13

DR. ROBERT A. CROVELLI "PROB/SIMULATION OF PETROLEUM PLAY POTENTIAL"
U.S. GEOLOGICAL SURVEY
DENVER FEDERAL CENTER
DENVER, CO 80225 SESSION NUMBER W34

GREGORY W. DIEHL 'VARIABLE BUFFER-SIZE MODEL & CLOSED N/WS'
DIVISION OF APPLIED SCIENCES (JOINT WITH RAJAN SURI)
HARVARD UNIVERSITY
CAMBRIDGE, MA 02138 SESSION NUMBER M71

PROFESSOR STUART J. DEUTSCH 'FROM ARIMA STRUCTURES ON'
SCHOOL OF INDUSTR & SYSTEMS ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GA 30332 SESSION NUMBER T41

DR. BHARAT DOSHI 'PROB MODELS FOR PROCESSOR SCHEDULES - APPROXS'
RM 4K-428
AT&T BELL LABORATORIES
HOLMDEL, NJ 07733 SESSION NUMBER W13

PROFESSOR E.A. ELSAYED 'MACHINE INTERFERENCE IN MANUFACTURING CELLS'
DEPARTMENT OF INDUSTRIAL ENGINEERING (JOINT WITH J.J. NORTON)
RUTGERS-THE STATE UNIVERSITY
P.O.BOX 909
PISCATAWAY, NJ 08854 SESSION NUMBER W51

DR. MARTIN J. FISCHER 'AUTOVON RECONFIGURATION-A CASE STUDY'
DEFENSE COMMUNICATION ENGINEERING CENTER (JOINT WITH DAVE CALABRESE)
1860 WIEHLE AVENUE
RESTON, VA 22090 SESSION NUMBER W52

PROFESSOR GEORGE S. FISHMAN 'ESTIMATING NETWORK RELIABILITY'
CURRICULUM IN OPERATIONS RESEARCH & SYSTEMS ANALYSIS
UNIVERSITY OF NORTH CAROLINA
CHAPEL HILL, NC 27514 SESSION NUMBER T3T

PROFESSOR ROBERT D. FOLEY 'COMPUTING RELIABILITY OF INCIA AVIONICS'
DEPARTMENT OF INDUSTRIAL ENGINEERING & OR
VPI & STATE UNIVERSITY
BLACKSBURG, VA 24061 SESSION NUMBER W13

PROFESSOR F.G. FOSTER 'SOME THEORY OF STOCH FLOW IN N/WS'
DEPARTMENT OF STATISTICS
TRINITY COLLEGE, UNIV OF DUBLIN
DUBLIN 2, IRELAND SESSION NUMBER ML1

PROFESSOR J. GANI 'EPIDEMICS WITH BUNCHING'
DEPARTMENT OF STATISTICS
UNIVERSITY OF KENTUCKY
LEXINGTON, KY 40506 SESSION NUMBER M72

HORAND GASSMANN 'CONDITIONAL PROB & CONDIT MEAN OF A MULTIVAR NORMAL'
FACULTY OF COMMERCE
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, BC V6T 1Y8, CANADA SESSION NUMBER W92

PROFESSOR DONALD GAVER 'RANDOM PARAMETER STOCH PROCESSES'
DEPARTMENT OF OPERATIONS RESEARCH (JOINT WITH J. LEHOCZKY & P. JACOBS)
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93943 SESSION NUMBER M22

PROFESSOR STANLEY GERSHWIN 'EFFICIENT DECOMP FOR APPROX TANDEM Q'S'
LABORATORY FOR INFO & DECISION SYSTEMS
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MA 02138 SESSION NUMBER M71

PROFESSOR PAUL GILBERT 'NUMERICAL PROBLEMS IN ESTIM OF DYNAMIC SYSTEMS'
SCIENCE AND ENGINEERING
UNIVERSITY OF OTTAWA
OTTAWA, ONTARIO K1N 6N5 SESSION NUMBER W92
CANADA

PROFESSOR PETER W. GLYNN 'GRADIENT ESTIMATION FOR GENERALIZED SMPS'
DEPARTMENT OF INDUSTRIAL ENGINEERING
UNIVERSITY OF WISCONSIN
MADISON, WI 53706 SESSION NUMBER T81

PROFESSOR AMRIT L. GOEL 'STOCH MODELS FOR SOFTWARE RELIABILITY'
DEPARTMENT OF COMPUTER & ELECTRICAL ENGIN
SYRACUSE UNIVERSITY
SYRACUSE, NY 13210 SESSION NUMBER W61

A. GOYAL (SEE S.S. LAVENBERG)
T.J. WATSON RESEARCH CENTER
IBM
YORKTOWN HEIGHTS, NY 10598 SESSION NUMBER T32

PROFESSOR WINFRIED GRASSMANN 'IS THIS AN M/M/C QUEUE?'
DEPARTMENT OF COMPUTATIONAL SCIENCE
UNIVERSITY OF SASKATCHEWAN
SASKATOON, SASK., CANADA S7N 0W0 SESSION NUMBER M21

PROFESSOR HENRY L. GRAY 'THE G-SPECTRAL ESTIMATOR'
DEPARTMENT OF STATISTICS
SOUTHERN METHODIST UNIVERSITY
DALLAS, TX 75275 SESSION NUMBER T41

PROFESSOR LINDA GREEN 'ALTERNATIVE REALITIES: CHANGING VIEWS...'
GRADUATE SCHOOL OF BUSINESS
COLUMBIA UNIVERSITY
NEW YORK, NY 10027 SESSION NUMBER W52

DR. ARNOLD GREENLAND 'PROB MODELS FOR GEOGRAPHIC DATA BASES'
IIT RESEARCH INSTITUTE
5100 FORBES BOULEVARD
LANHAM, MD 20706 SESSION NUMBER W34

DR. SHLOMO HALFIN 'THE SHORTEST QUEUE PROBLEM'
BELL COMMUNICATIONS RESEARCH
600 MOUNTAIN AVENUE
MURRAY HILL, NJ 07974 SESSION NUMBER WL1

DR. DAVID HARRINGTON 'MARTINGALE METHS & STOCH CALC IN CLINICAL TRIALS'
DANA-FARBER CANCER INSTITUTE
44 BINNEY STREET
BOSTON, MA 02115 SESSION NUMBER W61

DR. DAVID I. HEIMANN 'RISK PROFILES FOR SOME HIGH CONSEQUENCE EVENTS'
DOT TRANSPORTATION SYSTEMS CENTER (JOINT WITH T.S. GLICKMAN)
KENDALL SQUARE
CAMBRIDGE, MA 02142 SESSION NUMBER W91

DR. DANIEL P. HEYMAN 'ASYMPT MARG INDEP IN LARGE LOSS N/W'
BELL COMMUNICATIONS RESEARCH
RM. 4M336
HOLMDEL, NJ 07733 SESSION NUMBER M12

PROFESSOR Y.C. HO 'AGG & PERTURB ANALYSIS OF Q N/WS & MANUF SYSTEMS'
PIERCE HALL (JOINT WITH P.Q. YANG)
HARVARD UNIVERSITY
CAMBRIDGE, MA 02138 SESSION NUMBER W51

PROFESSOR DONALD L. IGLEHART 'BIV CLT FOR MEAN & VAR ESTIM OF REGEN PROC'
DEPARTMENT OF OPERATIONS RESEARCH (JOINT WITH PETER W. GLYNN)
STANFORD UNIVERSITY
STANFORD, CA 94305 SESSION NUMBER M12

PROFESSOR PATRICIA JACOBS 'RANDOM PARAMETER STOCH PROCESSES'
DEPARTMENT OF OPERATIONS RESEARCH (JOINT WITH D. GAVER & J. LEHOCZKY)
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93943 SESSION NUMER M22

DR. DAVID L. JAGERMAN 'NUMERICAL CALCULATION OF LAPLACE TRANSFORMS'
AT&T BELL LABORATORIES
HOLMDEL, NJ 07733 SESSION NUMBER W91

DR. N.K. JAISWAL 'PROB ANALYSIS OF COMBAT MODELS'
INSTITUTE FOR SYSTEMS STUDIES & ANALYSIS
T-44, METCALFE HOUSE
DELHI-110054
INDIA SESSION NUMBER WL1

PROFESSOR KYUNG Y. JO 'DECOMP APPROX OF QUEUEING N/W CONTROL'
DEPARTMENT OF SYSTEMS ENGINEERING
GEORGE MASON UNIVERSITY
FAIRFAX, VA 22030 SESSION NUMBER T81

PROF. V. KACHITVICHYANUKUL 'NORMAL RANDOM VARIATE GENERATION'
INDUSTRIAL & MANAGEMENT ENGINEERING
THE UNIVERSITY OF IOWA
IOWA CITY, IA 52242 SESSION NUMBER W92

PROFESSOR FRANK KAMINSKY 'AN SQC SYSTEM FOR ANAL OF ELECTRO-MECH...'
DEPARTMENT OF INDUSTRIAL ENGINEERING & OR (JOINT WITH D. SONDERMAN)
UNIVERSITY OF MASSACHUSETTS
AMHERST, MA 01004 SESSION NUMBER W51

PROFESSOR ALAN F. KARR 'STAT INFERENCE FOR RANDOM FIELDS ...'
DEPARTMENT OF MATHEMATICAL SCIENCES
THE JOHNS HOPKINS UNIVERSITY
BALTIMORE, MD 21218 SESSION NUMBER M22

PROFESSOR JULIAN KEILSON 'REAL WORLD ISSUES IN PROBABILITY MODELING'
GRADUATE SCHOOL OF MANAGEMENT
UNIVERSITY OF ROCHESTER
ROCHESTER, NY 14627 SESSION NUMBER W5T

PROFESSOR CHRISTINA M.L. KELTON 'COMP OF INFERENCE TECH FOR MARKOV PROC'
DEPARTMENT OF ECONOMICS
WAYNE STATE UNIVERSITY (JOINT WITH W.D. KELTON)
DETROIT, MI 48202 SESSION NUMBER M22

PROFESSOR W.D. KELTON 'COMP OF INFERENCE TECH FOR MARKOV PROC'
DEPARTMENT OF INDUSTRIAL & OPERATIONS ENGIN
UNIVERSITY OF MICHIGAN (JOINT WITH CHRISTINA KELTON)
ANN ARBOR, MI 48109 SESSION NUMBER M22

MASAAKI KIJIMA 'NUMERICAL EXPLOR OF A BIVARIATE LINDLEY PROC'
GRADUATE SCHOOL OF MANAGEMENT (JOINT WITH USHIO SUMITA)
UNIVERSITY OF ROCHESTER
ROCHESTER, NY 14627 SESION NUMBER T33

SUNG CHUL KIM 'SOME ORDER RELATIONS IN JACKSON N/WS'
DEPARTMENT OF IE & OPERATIONS RESEARCH (JOINT WITH DAVID YAO)
COLUMBIA UNIVERSITY
NEW YORK, NY 10027

DR. JOHN F. KITCHIN 'RESOLVING REGEN STOCH MODELS TO DETERM ...'
QUALITY ASSURANCE TECHNOLOGY
BELL COMMUNICATIONS RESEARCH
CRAWFORD CORNERS ROAD
HOLMDEL, NJ 07733 SESSION NUMBER W61

PROFESSOR PETER KOLESAR 'ALTERNATIVE REALITIES: CHANGING VIEWS...'
GRADUATE SCHOOL OF BUSINESS (JOINT WITH LINDA GREEN)
COLUMBIA UNIVERSITY
NEW YORK, NY 10027 SESSION NUMBER W52

DR. MARTIN KRAKOWSKI 'UNFINISHED WORK IN M/G/1 AND ITS OMNI TRANS'
5301 WESTBARD CIRCLE, #237
BETHESDA, MD 20816 SESSION NUMBER W13

PROFESSOR V.G. KULKARNI 'SHORTEST PATHS IN MARKOV NETWORKS'
CURRICULUM IN OR & SYSTEMS ANALYSIS
UNIVERSITY OF NORTH CAROLINA
CHAPEL HILL, NC 27514 SESSION NUMBER T81

BERNARD LAMOND 'ON INSENSITIVE BOUNDS & NUMER RESULTS FOR TANDEM QS'
FACULTY OF COMMERCE & BUSINESS ADMIN (JOINT WITH NICO VAN DIJK)
UNIVERSITY OF BRITISH COLUMBIA
VANCOUVER, BC V6T 1Y8, CANADA SESSION NUMBER T82

DR. STEPHEN S. LAVENBERG 'PROB MODELING OF COMPUTER SYST AVAIL'
T.J. WATSON RESEARCH CENTER (JOINT WITH W. CARTER, A. GOYAL &
INTERNATIONAL BUSINESS MACHINES AND K. TRIVEDI)
YORKTOWN HEIGHTS, NY 10598 SESSION NUMBER T32

PROFESSOR LARRY LEEMIS 'A GENERAL MODEL FOR LIFETIMES'
SCHOOL OF INDUSTRIAL ENGINEERING
UNIVERSITY OF OKLAHOMA
NORMAN, OK 73019 SESSION NUMBER W92

PROFESSOR JOHN P. LEHOCZKY 'RANDOM PARAMETER STOCH PROCESSES'
DEPARTMENT OF STATISTICS (JOINT WITH D. GAVER AND P. JACOBS)
CARNEGIE-MELLON UNIVERSITY
PITTSBURGH, PA 15213 SESSION NUMBER M22

PROFESSOR PETER A.W. LEWIS 'NON-NORMAL TIME SERIES... '
DEPARTMENT OF OPERATIONS RESEARCH
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93943 SESSION NUMBER T41

DR. DAVID LUCANTONI 'ALGORITHMS FOR WIDE CLASS OF GI/G/1 QS'
2M605
BELL LABORATORIES
HOLMDEL, NJ 07733 SESSION NUMBER M73

DR. PETER MALPASS 'QUEUEING ANALYSIS OF A TELECOMM NODE'
CONTEL INFORMATION SYSTEMS (JOINT WITH PETER PURDUE)
11781 LEE-JACKSON HIGHWAY
FAIRFAX, VA 22033 SESSION NUMBER W52

PROFESSOR WILLIAM G. MARCHAL 'AN EXTENSION OF THE M/G/1 HEAVY TRAF APPROX'
COMPUTER SYSTEMS & PRODUCTION MGMT DEPT.
UNIVERSITY OF TOLEDO
TOLEDO, OH 43606 SESSION NUMBER W13

PROFESSOR FEDERICO MARCHETTI 'ANALYTICAL & NUM TREATMENT OF A CANCER MODEL'
DIPARTIMENTO DI MATEMATICA (JOINT WITH DAVIS COVELL)
UNIVERSITA LA SAPIENZA
I-00184 ROMA, ITALY SESSION NUMBER W91

PROFESSOR JOHN H. MCCRAY 'A QUASI-BAYESIAN CONJECTURE'
SCHOOL OF BUSINESS ADMINISTRATION
COLLEGE OF WILLIAM AND MARY
WILLIAMSBURG, VA 23185 SESSION NUMBER W92

DR. JAMES MCKENNA 'COMPUT ASPECTS OF QUEUING NETWORK THEORY'
AT&T BELL LABORATORIES
600 MOUNTAIN AVENUE
MURRAY HILL, NJ 07974 SESSION NUMBER M11

DR. KATHLEEN S. MEIER 'FITTING MARKOV-MODULATED POISSON PROCS'
413 BROOKVIEW DRIVE
MILLERSVILLE, PA 17551 SESSION NUMBER M21

PROFESSOR YASH MITTAL 'TESTS FOR CHANGE POINTS'
DEPARTMENT OF STATISTICS
VPI & STATE UNIVERSITY
BLACKSBURG, VA 24061 SESSION NUMBER M22

M. P. MUSSI 'OPTIMIZATION & PERF EVAL IN PARALLELIZATION OF PART PHYS'
INRIA (JOINT WITH W. JALBY & J. MAILLARD)
B.P. 105
78153 LE CHESNAY
CEDEX, FRANCE SESSION NUMBER M72

PROFESSOR MARCEL F. NEUTS 'PROFILE CURVES OF QUEUES'
DEPARTMENT OF MATHEMATICAL SCIENCE
UNIVERSITY OF DELAWARE
NEWARK, DE 19716 SESSION NUMBER M1T

J.J. NORTON 'MACHINE INTERFERENCE IN MANUFACTURING CELLS'
DEPARTMENT OF INDUSTRIAL ENGINEERING (JOINT WITH E.A. ELSAYED)
RUTGERS - THE STATE UNIVERSITY
PISCATAWAY, NJ 08854 SESSION NUMBER W51

DR. TEUNIS J. OTT 'CLOCKED OPERATING SYSTEMS, QS & ALMOST PHASE TYPES'
BELL COMMUNICATIONS RESEARCH
HOLMDEL, NJ 07733 SESSION NUMBER M73

PROFESSOR EMANUEL PARZEN 'TIME SERIES MODEL ID AND QUANTILE SPECTRAL ANAL'
INSTITUTE OF STATISTICS
TEXAS A&M UNIVERSITY
COLLEGE STATION, TX 77843 SESSION NUMBER T4T

PROFESSOR HARRY PERROS 'APPROX ANAL OF EXPO Q N/WS W/BLOCKING'
DEPARTMENT OF COMPUTER SCIENCE (JOINT WITH TAYFUR ALTIOK)
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NC 27650 SESSION NUMBER M71

PROFESSOR JOSEPH D. PETRUCCELLI 'A MULTIPLE THRESHOLD AR(1) MODEL'
DEPARTMENT OF MATHEMATICAL SCIENCES (JOINT WITH S. WOOLFORD, K.S. CHAN,
WORCESTER POLYTECHNIC INSTITUTE AND H. TONG)
WORCESTER, MA 01609 SESSION NUMBER T42

DR. STEVE PINCUS 'A POSTERIORI PROB OF ZERO DELAY FOR TRAFFIC DATA'
BELL COMMUNICATIONS RESEARCH (JOINT WITH MICHAEL SAKS)
185 MONMOUTH PKWY - 1H301
WEST LONG BRANCH, NJ 07764 SESSION NUMBER T82

PROFESSOR STEPHEN POLLOCK 'APPROXS IN MODELS LEAD TO APPROXS IN SOLNS'
DEPT. OF INDUSTRIAL & OPERATIONS ENGINEERING
UNIVERSITY OF MICHIGAN
ANN ARBOR, MI 48104 SESSION NUMBER T32

MR. S.R.K. PRASAD, DIRECTOR 'STUDIES OF CHEM REACTORS USING PROBABILITY'
KRISHNA INDUSTRIAL CORP., LTD. (JOINT WITH C.M.K. SELVARAJ & C.A. BASHA)
6/34, RACE COURSE ROAD
COIMBATORE - 641 018, INDIA SESSION NUMBER M72

PROFESSOR PETER PURDUE 'QUEUING ANALYSIS OF A TELECOMM NODE'
DEPARTMENT OF STATISTICS (JOINT WITH PETER MALPASS)
UNIVERSITY OF KENTUCKY
LEXINGTON, KY 40506 SESSION NUMBER W52

PROFESSOR M.F. RAMALHOTO 'STAT PROBS IN RANDOM TRANSLATIONS OF SPP'
DEPARTMENT OF MATHEMATICS
INSTITUTO SUPERIOR TECNICO
AV. ROVISCO PAIS
1000 LISBOA - PORTUGAL SESSION NUMBER ML1

DR. V. RAMASWAMI 'STAT WAITING TIME IN MULTI-SERVER QS WITH PHASE ...'
BELL COMMUNICATIONS RESEARCH
RM. 4L413
HOLMDEL, NJ 07733 SESSION NUMBER M73

DR. MARTIN I. REIMAN 'ISSUES RE: INTERPOLATION APPROXIMATIONS'
2C460 BELL LABS (JOINT WITH BURTON SIMON)
600 MOUNTAIN AVENUE
MURRAY HILL, NJ 07974 SESSION NUMBER T32

PROFESSOR MATTHEW ROSENSHINE 'OUTPUT PROCESS FROM SERIES OF M/M/1S'
DEPT OF INDUSTRIAL & MGMT SYSTEMS ENGINEERING
PENNSYLVANIA STATE UNIVERSITY (JOINT WITH T.I. MILES & C.D. PEGDEN)
UNIVERSITY PARK, PA 16801 SESSION NUMBER T31

PROFESSOR DENIZ SANDHU 'ON THE ANALYSIS & SIMULATION OF INTEGR VOICE ...'
ELECTRICAL, COMPUTER & SYSTEMS ENGINEERING DEPT.
RENSSELAER POLYTECHNIC INSTITUTE (JOINT WITH MORTON POSNER)
TROY, NY 12181 SESSION NUMBER W34

PROFESSOR BRUCE SCHMEISER 'CONTROL VARIATE ESTIMATORS'
SCHOOL OF INDUSTRIAL ENGINEERING (JOINT WITH JAMES J. SWAIN)
PURDUE UNIVERSITY
WEST LAFAYETTE, IN 47907 SESSION NUMBER T31

PROFESSOR RICHARD F. SERFOZO 'ASYMPTOTIC BEHAVIOR OF MAX Q LENGTHS'
SCHOOL OF INDUSTRIAL AND SYSTEMS ENGINEERING
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GA 30332 SESSION NUMBER M12

PROFESSOR J. GEORGE SHANTIKUMAR 'UNIFORMIZATION & HYBRID MODELS'
MANAGEMENT SCIENCE GROUP
UNIVERSITY OF CALIFORNIA
BERKELEY, CA 94720 SESSION NUMBER T31

DR. BURTON SIMON 'ISSUES RE: INTERPOLATION APPROXIMATIONS'
AT&T INFORMATION SYSTEM LABS (JOINT WITH MARTIN REIMAN)
DENVER, CO 80234 SESSION NUMBER T32

PROFESSOR NOZER D. SINGPURWALLA 'RELEVANCE OF BAYESIAN PARADIGM IN A/P'
DEPARTMENT OF OPERATIONS RESEARCH
THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC 20052 SESSION NUMBER TE1

PROFESSOR RICHARD SMITH 'STATISTICS OF THE 3-PARAMETER WEIBULL'
DEPARTMENT OF STATISTICS
IMPERIAL COLLEGE
180 QUEENSGATE
LONDON SW7 2BZ ENGLAND SESSION NUMBER W6T

DR. WRAY SMITH 'FRACTIONALLY DIFFERENCED MODELS FOR WATER QUAL T/S'
THE GEORGE WASHINGTON UNIVERSITY
P.O. BOX 19067
WASHINGTON, DC 20036 SESSION NUMBER T42

PROFESSOR MATTHEW J. SOBEL 'COMPUT SOLNS OF THE TRUNC MOMENT PROBLEM'
COLLEGE OF MANAGEMENT (JOINT WITH KUN-JEN CHUNG)
GEORGIA INSTITUTE OF TECHNOLOGY
ATLANTA, GA 30332 SESSION NUMBER M11

PROFESSOR MARTIN K. SOLOMON (SEE ROBERT COOPER)
DEPARTMENT OF COMPUTER & INFORMATION SYSTEMS
FLORIDA ATLANTIC UNIVERSITY
BOCA RATON, FL 33431 SESSION NUMBER W13

PROFESSOR DAVID SONDERMAN "AN SQC SYSTEM FOR ANAL OF ELECTRO-MECH..."
DEPARTMENT OF INDUSTRIAL ENGINEERING & OR (JOINT WITH F. KAMINSKY)
UNIVERSITY OF MASSACHUSETTS
AMHERST, MA 01004 SESSION NUMBER W51

PROFESSOR KATHRYN STECKE "MATH MODELS USED TO SOLVE DESIGN..."
GRADUATE SCHOOL OF BUSINESS
THE UNIVERSITY OF MICHIGAN
ANN ARBOR, MI 48109 SESSION NUMBER W51

PROFESSOR WILLIAM J. STEWART "QUEUING MODELS, BLOCK MATRICES, ETC."
DEPARTMENT OF COMPUTER SCIENCE (JOINT WITH WEI-LU CAO)
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NC 27650 SESSION NUMBER T32

PROFESSOR SHALER STIDHAM "STABLE REC PROCS FOR NUM COMP"
DEPARTMENT OF INDUSTRIAL ENGINEERING
NORTH CAROLINA STATE UNIVERSITY
RALEIGH, NC 27650 SESSION NUMBER M11

PROFESSOR USHIO SUMITA "NUMERICAL EXPLOR OF A BIVARIATE LINDLEY PROC"
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